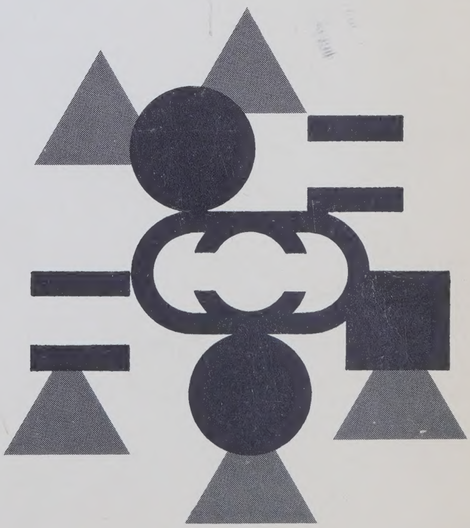
AN ENERGY POLICY FOR CANADA PHASE 1

VOLUME I - ANALYSIS



AN ENERGY POLICY FOR CANADA
–Phase 1

Volume I. ANALYSIS

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FOREWORD

Energy, how it is to be obtained and how used, has emerged as one of the major public questions of our time. With the growing complexity of the industrial economy, and increasing aspirations for a better life, the rate of demand for energy has been accelerating.

Because the sources of energy now employed are known to be finite, and in face of the increased demands on them, grave concern has grown up as to whether future supplies will be available, and available at a cost that will not negate our other aspirations. Grave concern has also emerged about the effect on the natural environment of present methods of acquiring, transporting and using energy sources.

The attainment of many of our national goals is dependent on our continued access to low-cost supplies of energy: the growth in our standards of living, as individuals and as nations; the improvement in the quality of life, in the choices available to us.

At the international level we have heard expressions of concern about the availability and cost of energy in the future. In Canada we have had the good fortune to be endowed with substantial supplies of all five main sources of energy: coal, oil and gas, hydro power and uranium. But with our climate, and with the transportation demands imposed on us by our vast land-area, our demand for energy is also substantial.

We in Canada are now on the threshold of some major discussions in the energy field. We must soon decide at what rate we are to develop our frontier sources of oil and gas, with all the implications that such development has for the lives of those that make their homes in those regions, for the environment of those areas and for the national economy.

Most of the major, accessible sources of hydroelectric potential have been, or are now being, harnessed. We must make decisions as to what form of thermal generation, fossil fuel or nuclear, is to meet the future demand for electric power.

To prepare for future challenges in the energy field we must get underway now scientific research and the development of technology. Decisions now as to how we employ our finite research and development resources will determine the ability to respond to the problems that will affect coming generations.

During the time that the studies reported on by this document have been underway, energy reports have been issued by the provinces of British Columbia, Alberta, Ontario and Quebec. The purpose of this report is to define more clearly the national framework into which provincial studies fit, to identify policy choices which must be made within the federal jurisdiction, and to provide a basis for choice by the Government and people of Canada.

The next step is one of consultation. Consultation with members of the public interested in the various facets of the energy question and with governments of the provinces. On the basis of the information which this report provides as to where we are, and where the various choices may lead us, and following those consultations, the Government of Canada will then reach the second phase of its approach to the energy problem of deciding how, and with what instruments our existing energy policies should be altered.

Hon. D. S. Macdonald

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GLOSSARY OF TERMS

ABBREVIATIONS

Mcf—one thousand standard cubic feet.

MMcf—one million standard cubic feet.

Bcf—one billion (one thousand million) standard cubic feet.

Tcf—one trillion (one thousand billion) standard cubic feet.

Btu—the amount of heat required to raise the temperature of one pound of water 1°F.

MMBtu—one million Btu's. This term is often used in comparing relative energy prices; for example, one Mcf of natural gas usually contains about one million Btu's, while a barrel of crude oil contains in the order of 6 million Btu's.

MMBbl/day—millions of barrels per day.

C.I.F.—this term means literally "including cost, insurance and freight" and refers to the cost of a commodity laid down at a certain port or location, including the above items.

OPEC—the Organization of Petroleum Exporting Countries including Abu Dhabi, Algeria, Indonesia, Iran, Iraq, Kuwait, Libya, Nigeria, Qatar, Saudi Arabia, and Venezuela.

NPC (national petroleum company)—a general term used herein to refer to a wholly or partially state owned and controlled petroleum company.

DEFINITIONS

1. *Alberta heavy oils*—these oils are somewhat transitional in character between the heavier oil-sand type bitumen deposits and conventional crude oil. They are highly viscous in nature and either do not flow or flow at very low rates under normal conditions, thus requiring either solvents or the injection of heat to induce normal flow.

2. *Alberta oil sands*—the oil sands are contained mainly in major deposits at Athabasca, Wabasca and Peace River and consist of a highly viscous bitumen-like crude oil mixed with sand. These deposits range from surface outcrops to overburden depths of up to 2,000 feet. Under normal conditions, the oil is tar-like in consistency and does not flow, thus requiring either mining techniques for its recovery or the injection of heat or solvents to reduce its viscosity and induce flow.

3. *BOE (barrels of oil equivalent)*—oil in barrels plus oil equivalent of gas converted on a thermal basis (6,000 cubic feet equivalent to one barrel) together expressed in barrels.

4. *City gate price*—in reference to the pricing of natural gas, the city gate price is normally considered to be the price paid by the city distributor (retailer) to the transmission company or supplier (wholesaler) at the junction of their facilities prior to the addition of the local utilities distribution charges.

5. *Constant (1972) dollars*—because of inflation the value of a Canadian dollar declines slightly every year. To eliminate this effect, values of goods and services are expressed in dollars of a particular year. Throughout this report 1972 dollars were used unless otherwise indicated.

6. *Conventional oil*—oil that will, under normal conditions, flow into a well bore and is recoverable by conventional technology.

7. *Economic rent*—although this term may assume a number of definitions, the one chosen for use in this paper is "that economic return (on land, labour or capital) over and above all of the costs of operation including depreciation, operating expenses, overhead, transportation costs and an adequate return on risk capital". Revenues in excess of this amount are defined as economic rent.

8. *Form value*—because of its physical form and burning characteristics natural gas can command a higher price to certain industrial users such as metallurgical, ceramic and glass plants. (See also Premium Value.)

9. *"in-situ" recovery techniques*—this term literally means the recovery "in place". As applied to the Alberta oil sands it means the separation of the oil or bitumen from the sand in place so that the oil is recovered at the surface and the sand remains in the reservoir.

10. *Interruptible gas*—some industrial gas purchasers, because of the nature of their use of gas or because they possess alternate heating facilities can accept delivery of gas from their supplier on an interruptible basis at the discretion of the supplier. Such gas is priced below normal industrial market prices.

11. *Life index or reserves/Production ratio*—this index is computed by dividing the remaining proved reserves of a resource by the current year's production rate to arrive at an index number relating to the number of years the proved resource would last at current consumption rates.

12. *Natural gas liquids* (N.G.L.)—are the low molecular weight hydrocarbons coproduced with natural gas: propane, butanes, and pentanes-plus.

13. *Non-conventional oil*—a viscous oil not amenable to production from a well bore by conventional technology. It includes, particularly, oil from the various oil sands which may be recovered by mining or thermal techniques.

14. *Off-peak gas*—refers to gas delivered to (normally) industrial consumers during periods of low consumption, usually the summer months.

15. *Original in-place reserves*—the oil or gas initially in-place within a pool, part of which is recoverable, and another part non-recoverable.

16. *Pipeline gas*—natural gas from which the impurities have been removed; saleable gas. (See also Raw gas.)

17. *Posted price*—up until the late 1950's the term posted price could be defined as the price at which oil companies operating in the international theatre listed their foreign crude oil for sale to non-affiliated third parties in arms length transactions. Subsequently, as price cutting occurred, and the relationship between the posted price and real crude trading prices was eroded, the term posted price has come to mean the price upon which host country taxes and royalties are based; in effect, a tax reference price.

18. *Premium value*—certain fuels command a higher price than others because of lower utilization costs, form value or clean-burning characteristics. Because of these factors, natural gas is a preferred fuel having a significant premium value in most markets.

19. *Primary energy*—refers to the amount of energy available to the final consumer (secondary energy) *plus* conversion losses and waste used by the energy supply industries themselves. Conversion losses, in this case, refer to losses in processing of refined petroleum products for example, or the losses due to thermal and mechanical inefficiencies resulting from the conversion of fossil fuels (coal, oil or natural gas) into electricity in thermal power generation plants.

20. *Proved reserves of oil and gas*—the volumes of oil and gas that can be demonstrated by geological and engineering data to be recoverable with reasonable certainty under existing economic and operating conditions.

21. *Raw gas*—natural gas as it is produced in its native state at the wellhead is water saturated and often contains liquid hydrocarbons and various impurities; the most common of which are hydrogen sulphide (H_2S) and carbon dioxide (CO_2). Raw gas must be processed prior to sale. Processing generally consists of dehydration, removal of most hydrocarbon liquids and the removal of carbon dioxide and hydrogen sulphide.

22. *Recoverable potential* (resources)—the quantities of oil and gas postulated to be present in sedimentary rocks and that are potentially available through intensive exploration and development.

23. *Refined products*—refers to the end products resulting from the refining of crude oil: propane, butane, gasoline, naphtha, kerosene, jet fuel, diesel, lubricating oil, heavy fuel oil, asphalt, coke, etc.

24. *Resource base*—in the context of this report, resource base refers to Canada's total potential domestic energy resources. Thus, the resource base includes currently proved and probable reserves and ultimate potential resources of oil, natural gas, coal, uranium, hydroelectric power and other forms of usable energy.

25. *Secondary energy*—this refers to the amount of energy actually available to, and used by, the consumer in its final form.

26. *Shut-in capacity*—this term is used in the oil and gas producing industry to mean the unused production capability of currently producing oil and gas wells or

shut-in oil and gas wells whether or not they are connected to the surface gathering and production facilities, plus the known production capability of proved oil and gas pools not presently on production. The term thus implies the maximum reasonable production capability of all known oil and/or gas reserves without regard for their current production status or the availability of surface production facilities.

27. *Stack gas scrubbing*—a general term referring to a large number of processes designed to remove pollutant gases and particulate matter from stack or chimney effluent.

28. *Ultimate recoverable potential*—the proved reserves (both produced and remaining) added to the recoverable potential.

INTRODUCTION

Canadians use more energy on a per capita basis than any nation of the world other than the United States. About one-quarter of our disposable income is used to purchase and operate equipment to provide heat, light and transportation.

Energy has been a pervasive factor of life since primitive man first employed fire to his use, and the majority of Canadians have become accustomed to a flick-of-a-switch life style. Energy in Canada provides the basic heat and light required for living, and also makes possible such frills and extravagances as the electric toothbrush. Energy heats and powers our homes, our offices and plants, our hospitals, our schools, colleges and universities, our private and public buildings, and our sports centres and places of entertainment. It propels our transportation; whether it be car and truck, bus and train, barge and ferry, or aircraft spanning the country and the globe. For a great many Canadians energy embraces their existence in all of its facets—work, leisure, and play. Even the camper or outdoorsman by the lonely lake or in the quiet forest trying to get away from it all probably drove or flew to the site, and is wearing clothing and using equipment that required energy in its manufacture. The energy input is inescapable.

This heavy reliance on energy in every aspect of our daily life makes energy policy everybody's concern. As individuals we have strong views on such matters as pollution, pipelines, native claims, export controls, etc.—all directly related with the need for and use of energy. Nearly every Canadian feels the country's energy policy affects him personally. We are not content to leave its development entirely to government or to the actions of free market. Today Canadians insist on participating in determining how Canada's energy resources will serve them.

Our personal policies towards energy may be contradictory. We may demand continued cheap power and yet be strongly opposed to the construction of more power stations in our own areas. Our actions often negate our expressed intentions; we drive separate high horsepowered cars to attend a meeting on the energy crisis; we elect aldermen on their promise to reduce traffic problems and then don't make full use of public transport systems. Successful national energy policies will need to reconcile some basic conflicts of interest, even at the level of the individual Canadian.

Our energy policies must cope with the fact that nature has frequently placed major Canadian energy resources in rather inconvenient places in relation to where energy is needed and used. In building Canada provincial boundaries were selected without regard to water or other resource distribution. It is not unnatural that, for example, the residents of Alberta may feel very differently about the price of natural gas than do those of Ontario. Each can argue that their position leads to the public benefit. Much of the strength and character of Canada lies in these

differences and the factors that give rise to them. Satisfactory energy policies must find a consistent yet flexible method of operation that will serve both national and regional interests.

There is a need for guidelines for federal and provincial activities. Energy policies must also reflect the needs and interests of the municipalities which facilitate the use of much of the nation's energy, private business which is dominantly responsible for producing and marketing energy, and the consumer who must derive a benefit from the total operation.

The challenge can be stated simply—to have energy policies ensuring the best management of our resources for the general welfare of Canadians. But a simple statement is misleading. Energy policies can no longer deal with one energy commodity in isolation, with no consideration for the consequences in other areas of the energy industry. Energy policies must be developed on the foundation of thorough analyses of various options and the impact of those options on the industry itself, and most importantly on all aspects of Canadian economic and social policies.

This report has been prepared with the objective of presenting to the people of Canada the results of continuing in-depth studies of key elements which lead to the development of energy policies. It is hoped that the report will help in establishing a sound basis for an informed public debate of all the issues. The studies on which the document is based are being improved as the basic data are refined. They represent the best analyses available at this time in a rapidly changing scene. For example, it is fully recognized that the federal government's continuing program to develop a more accurate inventory of energy resources may change the estimates contained in this report. Similarly, improved techniques will be developed to more accurately assess the economic impact of alternative development options.

Policy decisions, however, must be made on the basis of a knowledge base existing at any one point in time. This document, coupled with information which will now flow in as response from the provinces, the energy industries and the general public, represents that base.

Having had the benefit of such a response, it is proposed that a second report be prepared setting forth the major issues existing in the energy field and policy recommendations to deal with them to best benefit Canada.

The procedure in carrying out the program of energy policy studies during the past two years has been to encourage participation by any agency of government having responsibilities bearing on energy policy. This ensures consideration of relevant matters from all points of view. Some specialized studies were commissioned to consultants. These reports were used as sources of information or opinion where they were not otherwise expertly available within government. The project has been coordinated by the Department of Energy, Mines and Resources where much of the analytical work and writing has been done with help from members of the staff of the National Energy Board, Atomic Energy of Canada Ltd., the Atomic Energy Control Board and Eldorado Nuclear Ltd.

ENERGY POLICY—CONCERNS AND CONSTRAINTS

Energy resources and industries emerge at every point in Canadian life. Policy decisions have widespread and often unexpected impacts as they reverberate through the complexity of economic and social structures. Actions and decisions of all levels of governments and of private individuals in Canada and elsewhere, such as the managers of energy-related industry, also push and pull at the Canadian energy structure.

Some of the interactions and interrelationships are illustrated in the chart. A policy decision at any one point in the indicated areas of interest causes a chain reaction. Influencing energy might be compared to poking into a tightly-filled balloon which then reacts and expands in other areas.

There is no simple way of determining a cause and effect relationship in making energy policy decisions. The widespread range of influence of any given decision can be illustrated by taking a single example of the many policy decisions which are possible.

Follow the reaction effect through the chart in the event of a decision being made to curtail further exports of energy, keeping in mind that this theoretical decision is broadly based and does not even consider which kind of energy.

1. Resource Development—What would be the impact on the rate of resource development and the resource industries?

2. Resource Adequacy—To what extent would it improve the adequacy of supply of resources or reduce exploration for new supplies?

3. Trade and Access—How would our trade and access with other countries on this and other commodities be affected?

4. Balance of Payments—How would it affect our international balance of payments position?

5. Capital—To what extent would it ease our capital requirements, or alternatively, would such a decision tend to divert foreign sources of capital away from Canada?

6. Environment—Would the resulting chain of circumstances aid our environmental objectives (by avoiding or postponing a resource development project) or run counter to that goal by reducing the ability of the economy to pay for pollution abatement measures?

7. Ownership and Control—Would the reduction in capital reduce the degree of foreign ownership to any extent?

8. Regional Impact—Would it have a serious impact on any particular regional economy?

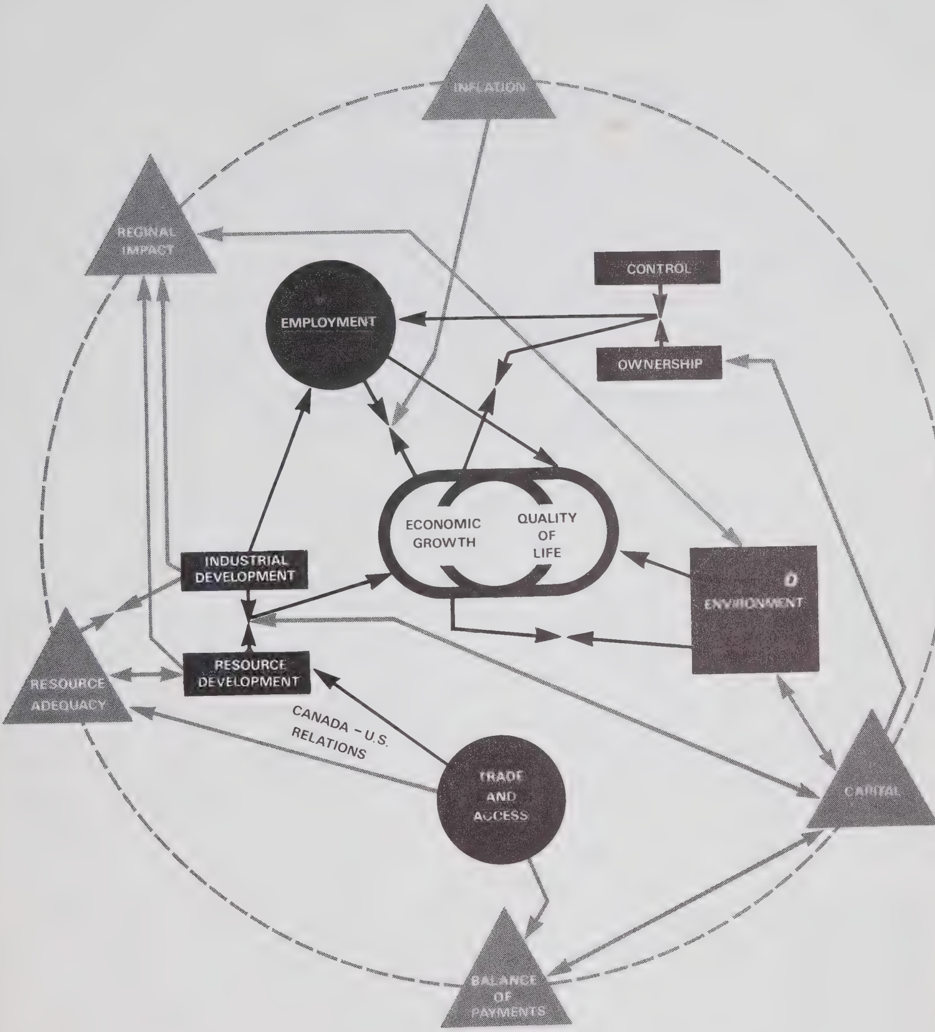
9. Industrial Development—Would the curtailment of exports have any bearing on the rate of, and direction of, industrial development in Canada?

10. Employment—What employment opportunities would be lost and could they be compensated for by greater activity in other segments of the economy?

11. Inflation—How would the consequent impact on employment and economic growth affect the rate of inflation in the economy?

12. Economic Growth—Quality of Life—How would all of these reactions affect general economic growth and quality of life objectives?

A knowledge of the facts and a consensus that indicates Canadian aspirations will permit the formulation of the best energy policies appropriate at any given point. This report explores the concerns and constraints indicated by the chart so that the reader can have a better understanding of the consequences throughout the economy of energy policy decisions.



INFLATION
REGINAL IMPACT
CONTROL
EMPLOYMENT
OWNERSHIP
ECONOMIC GROWTH
QUALITY OF LIFE
INDUSTRIAL DEVELOPMENT
ENVIRONMENT
RESOURCE ADEQUACY
RESOURCE DEVELOPMENT
CANADA – U.S. RELATIONS
TRADE AND ACCESS
CAPITAL
BALANCE OF PAYMENTS

SUMMARY OF ANALYSIS

As noted in the foregoing, which sets forth the concerns and constraints which relate to energy policy, an apparently simple decision on a single energy problem can set off a chain of events which impact through many areas of the Canadian economy. Because of this complex sequence of inter-actions a brief summary of the analysis runs the danger of being contradictory or misleading. Accordingly, the reader is cautioned that the following Summary of Analysis should be read in conjunction with the main body of the text and the appendices which set forth the various assumptions made and areas of deficiency in data or analysis.

With this expression of caution, here are the main findings of the studies:

Energy and the Quality of Life in Canada

Canadians are heavy users of energy. Our per capita use of energy is the second highest of any nation in the world. On the average, each of us uses each year energy equivalent to that contained in 55 barrels of oil. Much of this energy is required to achieve a reasonable material standard of living in Canada, but an important part also goes to enable Canadians to enjoy, by choice, the life style and the activities that they find satisfying. Our aspirations and concepts of desirable life styles are continually changing, but improvements in the quality of our lives are not likely to be accompanied by a future reduction in the net per capita use of energy. To a large degree the quality of life enjoyed by Canadians is, and will continue to be, determined by how we employ energy not needed for our basic material existence.

Although adequate energy is essential to a high quality of life, increase in the use of energy will not necessarily lead to improvement in the quality of life. Improvement may depend largely on having a range of choices available, and on the ability to make choices with a balanced perspective of immediate and long-term consequences. Our energy policies play an important role in enabling Canadians to have adequate energy for their needs, and in directing its use towards attainment of the objective of a satisfactory and improving quality of life.

A Quarter Century of Development

Primary energy consumption in Canada has tripled during the past 25 years. Oil and gas now meet almost two-thirds of total energy consumption compared with less than one-quarter 25 years ago, while coal's share has declined from

one-half to one-tenth. The other major energy source is hydroelectricity which has been meeting about one-quarter of total energy needs since the late 1950's. Nuclear energy has yet to make a significant impact on the total national scene.

The growth of the energy industries during the past 25 years has now established them as a major component of the Canadian economy with a primary production value in 1972 of $5 billion. In that year, energy trade had a favourable balance of $634 million compared with a deficit of $300 million in 1960. They continue to be major growth industries and in 1972 accounted for almost one-fifth of total capital investment in Canada. Their importance in regional development is indicated by the $3.6 billion of oil and gas revenues that have accrued to the Alberta Government since 1947 and by the industrial development that has been stimulated in Western Canada. Other elements of growth relate to the 6.7 per cent average annual increase in the demand for electricity, which has been considerably above the average annual increase in total energy demand of 4.3 per cent.

The Energy Industries—What They Are

In 1972 the oil industry produced 1.7 million barrels of crude oil daily, exported 1.1 million barrels of crude and products and imported 900,000 barrels daily of crude and products. The potential oil resource base appears to be large, but the recent rapid production increase has led to a decline in the proved reserves to annual production ratio from 24.5 to 15 in the period 1966-1972. Export controls were placed on oil in March of 1973. As the resource base in the Prairie Provinces is now largely delineated, exploration is being conducted in the frontier areas of the far north and offshore and more active development is commencing in the Athabasca oil sands area. Rising world prices are serving to stimulate this new phase in Canadian oil development.

The natural gas industry in 1972 produced 2,500 billion cubic feet and exported 1,000 billion cubic feet. As in the case of oil, the potential resource base appears large but new reserves must be developed for the domestic market before there can be any further growth in exports. Annual reserve additions will have to increase substantially from the 1970 increase of 2,800 billion cubic feet if they are to support a pipeline for the transport of Arctic reserves. As the natural gas industry enters a new phase of expansion based on production from frontier areas, the effect of price increases will become increasingly acute.

In 1972 the coal industry produced 20.6 million tons of coal, exported 9.4 million tons of coal and 260 thousand tons of coke and imported 19.3 million tons of these products. Exports have risen markedly since 1969 and imports have increased by 50 per cent since 1962. Canada's coal resource base is very large but much more information must be obtained as to its quality and mineability for purposes of determining future export policy and best use within Canada.

The uranium industry reached its peak production in 1959 and then entered into a dramatic decline due to the loss of United States and United Kingdom markets. Federal government action in establishing two successive uranium stockpiling programs prevented a complete collapse of the industry. The era

of large commercial uranium sales began in 1966 and one-quarter of presently known low-cost reserves are now under contract. The resource base is large and in no way limits foreseeable production and marketing plans. While the history of the uranium producing industry has been one of boom, recession and now difficult revival, the program of nuclear research and development has proceeded slowly but steadily and the CANDU reactor now appears successfully established and is attracting world attention.

Electrical energy gross generation in 1972 was 238 billion kWh, almost double the 1963 output. Over the years exports and imports have been more or less in balance but in 1972 exports totalled 10,372 million kWh, about four times imports. The net exports represent 3.3 per cent of total Canadian generation. While trade in electrical energy is small in relation to production, it is important in terms of the mutual benefits to be gained through interconnected systems. New high voltage direct current technology and large nuclear units will lead to increasing interconnection between provincial power systems.

Federal Energy Policies

Energy in Canada has been moulded by detailed policies to meet unique Canadian conditions and needs. Our policies relating to energy are complex, diverse and incapable of simple formulation.

There are certain basic national objectives which have shaped the energy policies we have today. These objectives relate to adequate supplies of energy at competitive prices; the safeguarding of national security; the encouragement of energy resource development; the export of surplus energy supplies under terms that benefit the nation; the acquisition of energy supplies from abroad when they are more economic than domestic sources; and the alignment of energy policy objectives with other national objectives such as those relating to Canadian ownership and the protection of the natural environment.

Specific energy policies have been developed for each of the energy commodities and all of them should be subject to periodic review and assessment. Among the more important policies which now exist and which now warrant re-examination are the National Oil Policy and the related concept of the Ottawa Valley line; the regulations governing the setting of royalties and land rights for oil and gas activity; natural gas marketing policy particularly in relation to exports; coal export policy, and also coal import policy particularly as it relates to the possibility of alternate domestic supplies to the Ontario market; uranium marketing policy in relation to market expectations of the late 1970's and 1980's; and the National Power Policy, particularly in relation to further development of a nation-wide power grid concept and the implications of current provincial government hydroelectric resource projects and nuclear power developments to this concept. There are a number of policies common to all energy sources requiring continuing examination, particularly those relating to fiscal incentives, Canadian ownership, and further processing prior to export.

Federal and provincial responsibilities and interests in the energy field are intimately interrelated. No national policy can be contemplated without the fullest of intergovernmental consultations and consensus. Clearly the balance

of priorities between energy producer and consumer needs, regional interests, Canada's international competitive position and domestic prices for consumer goods are among the major questions which the federal government must weigh in the national interest. The process of arriving at satisfactory policies cannot be rapid or without difficulty. But resolution of these problems through bilateral and possibly multilateral discussion deserves the most sustained and determined effort.

Price Development of Fuels

(All prices and price increases in the report are expressed in constant 1972 dollars unless specifically noted.)

Canadian crude oil prices in the past have largely reflected U.S. crude price developments. By the end of this decade both United States and Canadian crude oil prices may move towards parity with laid-down costs of foreign crude, and, barring government policies to insulate Canadian prices from outside influence, new sources of energy in Canada will then be developed on the basis of prices reflecting international price movements. Although international crude oil prices declined in the 1960's, the 1971 and subsequent agreements between the OPEC countries and producers have already led to price increases and prices are expected to escalate through to 1985 with subsequently more moderate increases. In 1990 crude oil prices are forecast to be more than double today's prices.

Currently, natural gas is undervalued in most market territories when compared with competitive petroleum products. Gas from our frontier areas will cost much more. Greater flexibility in gas pricing is required if natural gas market values are to keep pace with increasing prices of competitive fuels. The cost of gas to distribution companies in 1990 could be more than twice current levels.

Metallurgical coal prices will be influenced by international trends and the cost to Canadian consumers could be $22-$25 a ton by 1980 compared to $19 today. As crude oil moves into the $5 to $7 a barrel range, coal liquefaction and gasification become feasible alternatives to conventional oil and gas. The cost of thermal coal will closely follow the cost of its oil and gas competition.

The current uranium (U_3O_8) price is near $6 a pound. By the year 2000 the price could rise to the point where it would be economic to recover some of those resources now delineated within the category of $10 to 15 per pound U_3O_8. As uranium costs account for only a small part of total nuclear power costs, however, a substantial uranium price increase could be accommodated with little impact on electricity production cost.

Canada's Energy Requirements

A forecast of Canada's future energy requirements and resource availability involves careful appraisals of future price expectations and of the trend of events in international resource availability as well as judgements on such matters as the impact of environmental standards. At best, the forecasting of energy demand and supply is a hazardous exercise but a continuing program of periodical review can improve the quality of forecasts.

Assuming no major changes in government policies or Canadian attitudes towards energy use or conservation, Canada's primary energy requirement by the

year 2000 is likely to be more than four times that of today. Based on a population estimate of 35 million in the year 2000 our per capita energy consumption would be 2.7 times that of 1970. Only minor increases in the efficiency of energy use are assumed in this forecast. Increasing prices for energy commodities will tend to moderate demand growth rates in the long run.

The forms of energy used directly by the consumer (secondary energy) in the year 2000 will not differ markedly from today; petroleum and natural gas will probably still account for almost 80 per cent, coal will drop from 6 per cent to 2 per cent and electricity will meet the remaining 18 to 20 per cent. The sources of power for electricity generation, however, will change significantly. Hydroelectric power is expected to decline to 30 per cent of total electricity generation from 76 per cent in 1970 while nuclear power will increase to some 44 per cent from 0.5 per cent in 1970. Thus, by the end of the century, nuclear power will provide more than 8 per cent of our total secondary energy consumption compared to much less than 1 per cent today.

There is considerable uncertainty about future energy consumption patterns. Changes in life styles of Canadians, changes in the economic structure of the nation, and government policies relating to the environment or conservation can have an important impact on energy demand. The consumption forecast could be 15 per cent higher or 25 per cent lower than the standard forecast for the year 2000 depending on these factors. The range could be even wider if economic growth or population levels are far different from standard projections.

Canadian Resources

Known uranium resources are estimated to be 400,000 tons of U_3O_8 available at prices up to \$15 per pound. Canada's cumulative domestic needs to the year 2000 could total 100,000 tons, while committed exports amount to some 60,000 tons. Thus Canada has a significant surplus over predicted requirements of low to medium cost uranium already proved or indicated. In addition there is estimated to be a further 500,000 tons of U_3O_8 available at \$15 per pound or less. The cost of uranium plays only a minor role in the total cost of nuclear power: an increase in the cost of uranium from the present \$6/pound to as high as \$50/pound for example would only raise electricity costs from a CANDU reactor by 2 mills from the present 7 mills per kilowatt hour.

At best, hydroelectric energy production might double to about 310 billion kWh by 1990. Growth of this source will be moderated thereafter by competition from nuclear power.

Canada has extensive coal reserves estimated at about 120 billion tons of which about 118 billion tons are in British Columbia, Alberta and Saskatchewan. These are geological estimates of reserves in place, but even on the basis of economic mineability criteria, Canada has sufficient mineable coal for the foreseeable future, at substantially greater production levels. These reserves are almost all in Western Canada; most of the economic Maritime coal has been extracted.

In the case of oil and gas, there is a considerable uncertainty about how large the resource base actually is. Most of the potential resources are expected to be found in Canada's as yet largely unexplored frontier areas. Canada's estimated petroleum resource potential can be grouped into three categories: conventional

oil, oil sands and heavy oils, and conventional natural gas. Estimates made by the federal government in 1972 and 1973 of potential recoverable conventional oil, are in the range of 83 to 118 billion barrels; in addition, there is a remaining proved reserve of about 10 billion barrels. The Alberta oil sands are very large but present technology and foreseeable prices would restrict recovery to about 65 billion barrels. Heavy oils, primarily located in central eastern Alberta, could provide an additional 30 billion barrels. Proved natural gas reserves yet to be produced total 53 trillion cubic feet. Estimates of gas potential, based on the 1972 and 1973 assessments, range from 711 to 834 trillion cubic feet. Analyses are presented in the report to indicate what portions of the estimated oil and gas potential resources may become available under specified price assumptions.

A Very Long Term Supply/Demand Projection

Projections through to the year 2050 show that electricity could provide about 90 per cent of all energy requirements by that time, as a result of a continuing development of the "electrical society". With an estimated population for 2050 of 2½ times that of today, the total amount of natural gas which would be needed to satisfy projected demands for that fuel over the intervening decades would be in the range of 500-600 trillion cubic feet. By the year 2050 natural gas may be replaced in all energy markets by electricity. Projections for oil suggest that Canada could satisfy her oil demand on the basis of Canadian conventional oil and oil sands mined by open-pit methods to beyond the year 2000; after that, oil sands developed by an "in situ" technique and oil from coal would be required in addition to more costly conventional oil and open-pit oil sands. Thus, present indications of Canada's oil and gas potential suggest that there is probably more than enough energy resources to meet domestic requirements until at least the year 2050 with a possibility of substantial amounts of oil and gas being available for export. These forecasts are made on the basis of prices in the year 2000 which would not exceed 10 mills per kWh for electricity, about $2 per thousand cubic feet for natural gas, and about $7 or $8 per barrel of oil (in 1972 dollars).

Inter-Energy Competition

The report presents findings on studies of two competitive markets: the market for various energy sources to supply electricity, and the competition between oil and natural gas.

For Canada as a whole, competition in the area of fueling electrical generation will be such that it is unlikely natural gas will increase in use very far beyond its present levels while coal and fuel oil will still hold an important share of this market until at least 1985. Hydro power will continue to grow substantially until the James Bay and Nelson River projects and projects in British Columbia are finished, but after completion of such projects, only minor additions in terms of national capacity are anticipated. Consequently towards the year 1990 most of the growth of Canadian electrical consumption will be supplied by nuclear energy, assuming satisfactory progress is made regarding waste disposal problems. Only in Alberta and Saskatchewan could coal still be meeting a large share of the new generation needs.

To illustrate the effect of changing prices on the relative demand growth for oil and natural gas, the current and future industrial market for oil and natural gas in the Toronto-Hamilton area was analysed. The analyses show that natural gas has not been priced to take advantage of increased costs of heavy fuel oil in the industrial market. Given the current inflexibility in gas pricing and a rising price for petroleum products, the relative differences between oil and gas prices will continue to grow. Accordingly, natural gas prices to industry in this area could increase significantly and still maintain a large part of the existing and potential market. If gas prices and wellhead values are to reflect competitive market forces, a more flexible system of gas pricing will have to be developed. Large volume sales of gas in western Europe and elsewhere in the world have recently been made by relating future contract prices to competitive fuel prices and other economic factors. The trend at present towards the establishment of more frequent re-determination periods for gas contracts indicates a movement in the same direction in Canada.

Security of Energy Supply

About 75 per cent of Canada's electrical energy is presently produced by domestic hydroelectric sources; more than one-half of the remainder is generated from imported fuels. The imported fuels are used in Ontario and the Maritime Provinces; all other regions are self-sufficient on the basis of Canadian energy sources. Although Ontario electrical generation stations could be supplied by coal from Western Canada sources rather than from U.S. mines, a considerable economic penalty to the consuming utility would be involved on the basis of current costs. Strengthened electrical interconnections between the Maritime Provinces and Quebec could reduce the dependence of the Maritimes on imported oil for electrical generation.

CANDU nuclear power stations use Canadian uranium and over 80 per cent of the total material and equipment required for nuclear power facilities is available from Canadian sources. Self-sufficiency in electricity supply will increase as nuclear generation is expanded.

There are abundant supplies of metallurgical coal in Canada but transportation economics still dictate that Ontario steel mills be supplied from U.S. sources. Fifty-two per cent of this imported coal comes from mines owned by the Canadian steel companies.

Only about one-half of the country's oil requirements is met from indigenous sources although there is a net surplus of oil supply on a trade balance basis. All regions east of the "Ottawa Valley line" are completely dependent on imports. In Eastern Canada, average stocks of oil are equivalent to about 40 days' requirements although at times available stocks would be somewhat higher. The degree of supply security could be improved by increasing stocks, extending Western Canada pipeline facilities to Eastern Canada, by working out international supply arrangements for times of emergency and by instituting a formal program of petroleum product rationing. Maintenance of the Ottawa Valley line in terms of the 1961 National Oil Policy protects Ontario's oil supply although with some economic penalty. Discovery of oil in commercial quantities off the east coast of

Canada or in the eastern Arctic could reduce or remove the security of supply problem.

Continuous assessments of security of supply are proceeding. To date, the security threat has not appeared serious enough to justify the very costly arrangements of supplying the region east of the Ottawa Valley with western Canadian crude oil.

Canadian Energy in an International Context

While Canada is self-sufficient in terms of energy production it does not have the potential to play a major role with regard to total North American needs. Our present exports to the United States meet less than 6 per cent of that country's oil and gas requirements, but do play an important role in providing secure supply and in meeting a large portion of the needs of specific regional markets. Future oil and gas exports from Canada to the United States or to new export markets will depend heavily on the success of frontier oil exploration and new production technology for the oil sands. Conceivably Canada's contribution to total U.S. oil and gas needs in the year 2000 could range from zero to 12 per cent. Canada is dependent on the United States for about 20 million tons of coal imports for Ontario needs. Over the years, the two nations have been more or less in balance on electrical energy trade. In 1972 there was a net electrical energy export from Canada equal to 3.3 per cent of total Canadian generation which represented about one-half of 1 per cent of U.S. needs.

The average export price for natural gas of about 30¢ per Mcf appears to be very low in relation to the rising price structure in the United States. However, if Canada wishes to insulate its domestic market from gas and oil price increases, some price control mechanism is necessary.

Although Canada has an adequate oil, gas, coal and uranium resource base in respect of its own foreseeable domestic requirements, our resources are not large in relation to total world resources and needs. For instance, oil shales and oil sands around the world contain more than 100 times the oil stored in our oil sands and these new international sources will begin to become available well before the end of the century as prices rise significantly. We are fortunate in having an assured energy resource self-sufficiency for a long period into the future, but Canada's future role as a world energy source will not be significant.

The Rate of Resource Development

The rate of development of our energy resources will be determined by the extent to which Canada wishes to meet export demands as well as domestic needs. It will also be affected by judgements as to the benefits that would accrue to Canada from alternate rates of development.

The "expected" rate of resource development would result if free market forces were allowed to operate within the existing framework of government action or influence. If the expectations about price developments and the Canadian resource base are approximately right, Canada could "expect" a rather high rate of resource development.

The "desired" rate of energy resource development could be higher or lower than the expected rate of resource development, depending on economic and political considerations which relate to national goals such as regional development, full employment, economic growth, environmental protection, resource adequacy, reasonable price stability, a favourable balance of payments, and an equitable distribution of rising incomes. Thus the appropriate or desired rate of development cannot be determined by considerations related to energy policy alone. It should be recognized, too, that the desired rate of resource development will change over time as economic and political attitudes evolve.

The "actual" rate of resource development will be determined by the success of the government in actually influencing the course of events. If the expected rate of development is thought to be either too high or too low, the government could endeavour to moderate or accelerate the pace by utilizing a mix of policy instruments. However, having regard to the difficulty of projecting what the "expected" rate of development will be, and to economic and political imponderables associated with defining the "desired" rate, as well as the lag in the application of the policy instruments, it is unlikely that the government could ever hope to fine-tune the short-term rate of development. With careful policy planning, however, it should be able to bring the long-term rate of energy development close to the desired rate.

Economic Rent from Canada's Oil and Natural Gas Resources

Production from oil and gas fields must furnish the industry with sufficient earnings to reimburse non-successful exploration expenditures and cover all the costs of the producing operation including depreciation, field operating expenses, overhead, transportation costs and an adequate return on risk capital. Revenues in excess of this amount are defined as "economic rent" and may accrue to either the industry or the owner of the resource, usually the government.

There are two different approaches by which Canada could obtain the benefits of economic rent. It could be collected by government in the form of royalties, taxes and bonus payments, or it could be realized by energy consumers in Canada by allowing them to benefit from low energy prices.

Both systems have their inadequacies. Rent collection by government through royalties applies only to the production stage, omitting possible revenues from the transportation, refining and marketing activities. In addition, the benefit of the rent collected in this manner is not readily apparent to end consumers of energy in Canada. To be fully effective and to deter inefficient or wasteful use of energy, controls on oil and gas prices would have to apply not only at the wellhead but also on a selective basis to a whole range of refined oil products.

The existing economic rent collection system for potential production from federal lands in Canada is not sufficiently flexible to be efficient under a variety of different cost conditions. While there are provisions to adjust royalties downwards to encourage production from small to medium size oil and gas pools with low well productivity, the present system would leave too much

rent in the hands of the industry in the event of prolific discoveries and highly profitable operations.

Comparison of Canada's fiscal terms—taxes and royalties—with those existing in other countries is not a very meaningful or useful exercise. Development costs and market conditions are very different throughout the world and appropriate fiscal terms in Canada must be designed to reflect the widely ranging economic nature of our resource base and the stage of current development.

A detailed review of Canada's present economic rent collection system is necessary if the country is to realize full benefits from the development of its frontier resources.

Energy and Employment

Four aspects of employment relative to the energy industries were examined in a preliminary way: direct employment, indirect and induced employment, regional employment, and the long-term development of Canada's labour force. Although further work in this important area of employment generated by energy industry activity is required, sufficient research has been done to indicate that important multiplier effects arise throughout the economy from all aspects of energy industry activity. In particular, the regional benefits of activities of the energy industry warrant careful attention as this industry offers employment benefits in areas where other industrial opportunities may be limited. Employment benefits cannot be adequately assessed on the basis of a national average. Consideration should be given to development of major projects ahead of a domestic need if that will assist a more orderly use of Canadian manpower and manufacturing potential and still be consistent with other government objectives. Canada's labour force is not expected to expand as rapidly in the 80's as it has recently and therefore, major energy projects in the 80's could exert greater pressures on the economy than is now the case.

The Role of Energy Costs in Canadian Industry

On the assumption that international oil and gas prices will increase in the future, and Canadian prices are allowed to parallel those increases, it is important to know what industrial sectors will be influenced and to what extent their competitive positions will be affected. It is concluded that higher energy costs could place some Canadian industries in a difficult position. In the aggregate, these industries account for about 1 per cent of Canada's real domestic product and 3 per cent of Canada's industrial production. These industries are essentially those that use natural gas extensively, such as the chemical industries that have to compete with similar industries operating in the U.S. Gulf Coast area using cheap natural gas feedstock. Increased prices would also create problems for a further group of industries which produces in aggregate about 10 per cent of the real domestic product and 30 per cent of Canada's industrial production. Some of these industries play a vital role in regional economic development. Attention may have to be given in the short term to ensure that some important Canadian industries such as pulp and paper and chemicals can accommodate to new price levels. There should, however, be no problem with the physical availability of natural gas to

industrial consumers in Canada whereas the projected "gas gap" in the United States suggests that over the long term the availability of new gas supplies rather than cost may become the overriding concern in that country.

Up-Grading of Energy Exports

There are six realistic opportunities for up-grading energy exports: uranium enrichment, the export of nuclear energy as electricity from CANDU reactors using Canadian uranium, coal gasification, export of oil products rather than crude oil, the export of synthetic natural gas rather than oil products, and export of petrochemicals rather than oil products or natural gas. The construction of a uranium enrichment plant and the export of nuclear energy to the United States are possibilities which require a decision on the part of Canadians on the question of using Canadian electrical energy to meet the power needs of other nations. Similarly, the environmental consequences of all of these possibilities must be balanced with the possible economic gains. A move towards exporting large volumes of refined petroleum products from western Canadian production would require industry cooperation in refinery construction and an interference with crude oil trade between affiliated companies.

Science and Technology in Energy Policy

It is important that research and development projects specific to Canada's needs be selected and that strong measures be taken to ensure that facilities, personnel and funds are available to support these activities at an adequate level within Canada. This in turn will lead to greater participation by the service and manufacturing industries in the major projects required to meet Canada's energy requirements.

The initial priorities for energy research and development must be addressed to fossil fuels as these are the resources which Canada will rely upon to carry it through this century into the age of nuclear fusion and other "advanced" technologies.

Among the most important areas are the Athabasca oil sands, and other heavy oil deposits in Western Canada; and the development of techniques and equipment to permit the efficient and safe exploration, production and transportation of the oil and gas resources from the Arctic landmass, from the ice-infested Arctic offshore areas, and from the sedimentary basins off the east and west coast.

Other important areas for research and technological development include:

—improvements to the CANDU reactor system;

—resolution of heavy water production problems;

—development of better and more economical methods of avoiding or controlling undesired effects on the environment;

—more efficient means of producing and utilizing energy, including the potential of Canada's large coal reserves;

—lower cost and more efficient electrical energy transmission and storage systems;

—energy resource inventory appraisals.

The role of government in energy matters in Canada will grow because of the traditional government role in electrical energy which will constitute an increasing share of energy supply in the future.

The Canadian nuclear generation program in the form of the CANDU reactor is further evidence of the prominence of state participation and the importance of this influence will increase inasmuch as 44 per cent of total electrical generation by the year 2000 will be from nuclear, compared with less than 3 per cent in 1972. The most extensive degree of federal government participation in the energy industries occurs in the uranium and nuclear industries. The government participates in all phases from exploration and mining to nuclear plant design and operation.

Much of the Canadian coal industry is in private investment hands. Foreign investors control 73 per cent of coal mining now being conducted in Canada. The concentration of the industry into the hands of the large corporations is a result of the large financial and technical challenges which must be met. There is federal participation in the Cape Breton coal mines, but this was brought about to meet social objectives relating to the maintenance of established communities and the diversification of the local economy. The question of state participation in Western Canada revolves primarily around the Dominion Coal Blocks and whether they should be opened up to the export market or conserved for future domestic use. The case for government participation in the coal industry is based largely on the value to the federal government of having working insights into coal industry operation, having regard to the growth potential of the coal resource base.

The proportion of state-held investment in the Canadian petroleum industry is less than 1 per cent and lies largely in the federal government's participation in Panarctic and the Quebec Government's investment in the Quebec Petroleum Operations Company (SOQUIP).

A "national petroleum company" (NPC) would provide a vehicle by which the government could seek to obtain better knowledge of the domestic and international petroleum industries thereby providing legislators with more valid law-making insights. An NPC could act to stimulate regional development in specific areas of Canada. It could serve as a centre for Canadian research, concentrating on unique Canadian opportunities and on the potential spin-offs in industrial activity. It could play a role in determining the criteria on which the government might base its policies regarding economic rent collection. It might also play an effective role on behalf of government in relations with other countries where their state companies were active. It could assist in the development of "headquarters" activities in Canada.

The decision by government to participate more extensively than at present in the energy industries rests largely on the question of whether such a decision should be based solely on economic criteria or whether government should become involved—for reasons which will accept lesser results on the commercial side for more beneficial results in terms of the development of the Canadian political community.

It may be, however, that to a large degree, the benefits of state participation in the petroleum industry could be realized by means already at hand and there is

no discernible void to be filled in Canada by the formation of a national petroleum company. Furthermore it can be argued that formation of such a company would serve as a cautionary signal to foreign-controlled companies thus initiating a slowdown of investment in Canada's oil and gas industry which could result in an eventual overall net cost to the Canadian taxpayer or energy consumer. With much of the most promising acreage already under permit or lease and with the already existing overabundance of service station outlets, to quote but two examples, it is probable that such a company could only be formed and become viable within a reasonable time horizon by buying-out or acquiring ongoing operations in each industry segment: exploration and production, transportation, refining and marketing. The cost of such an entry strategy would be high and would have to be borne initially by the taxpayer in the form of foregone revenues or high initial capital outlays, either of which would result in an increased tax burden. The justification for the formation of such a company, by definition would be mainly on other than economic grounds. The multiplicity of goals and objectives would almost certainly insure that any NPC would be commercially less efficient.

Energy Development—The Impact on Canada's Economy

An important policy question relates to whether energy resources which may be surplus to Canadian needs should be developed for export to what appears to be an insatiable U.S. and world market. The implications are fundamental to Canada's long-term economic strategy. A comprehensive answer should ideally be based on a wide range of analyses including the economic impact of both the investment and the operation phases of energy development, as well as on the possibility and impact of alternative developments in other sectors of the economy. The scope of this study at this point, is more limited. The economic impact of the investment phase and the implied large resource allocation to the energy economy is analysed. Implications of both the investment phase and some of the more important longer-term considerations are treated in a conceptual way.

Possible investment in energy development during the balance of this decade ranges from $42 billion to $68 billion. Five illustrative investment scenarios have been chosen for study purposes. In simplified terms the major differences are:

No Northern Development:	(A)	"Self-sufficiency" requiring $42 billion in investment
Mackenzie gas pipeline starting in 1975 :	(B)	"Standard Development" requiring $50 billion in investment
Mackenzie gas and oil pipelines :	(C)	"Extensive Development" requiring $60 billion in investment
The above plus a gas pipeline from the Arctic Islands :	(D)	"Maximum Development" requiring $68 billion in investment
Case B but with development of Mackenzie gas pipeline in 1977 :	(E)	"Delayed Development" requiring $49 billion in investment

The last four cases assume varying degrees of oil export above what would balance our expected imports. The "Self-sufficiency" option assumes no new natural gas exports and balances oil imports and exports.

The economic impacts of the five possible expenditure programs have been measured by using an econometric model and complemented by qualitative discussion. Viewed from the perspective of the control solution, the "Standard" and "Delayed" development cases, both costing about $50 billion could be absorbed by the Canadian economy without major consequences. In an under-utilized economic environment, there would be considerable benefits associated with this investment spending in terms of gains in employment and income. The "costs", such as price and exchange rate pressure would not be excessive and would be of short duration. Under tight market conditions the potential gains would be less. Viewed from the capital resource requirements of these cases, the priorities of our society would not have to be rearranged to accommodate them.

The three remaining cases range from a $42 billion Canadian "Self-sufficiency" case through a $60 billion "Extensive Development" to a $68 billion "Maximum Development" case. All three, albeit in different ways, would influence considerably the structure of Canada's economy and could involve the rearrangement of socio-economic objectives.

The "Self-sufficiency" case could indicate a choice by Canadians to forego income generation from resource development and call on these resources at a pace dictated by domestic demand. It would result in the release of scarce capital resources for other activities.

The "Extensive" and "Maximum Development" cases would endeavour to maximize income from resource development and in so doing could create severe pressures on prices and on the available productive facilities. The adoption of these programs would have to be accompanied by stringent monetary and fiscal restraints and would involve a reordering of economic and social priorities.

The Extent of Foreign Ownership and Control

Of the $31.4 billion of assets employed in the Canadian energy industries at the end of 1970, $11.0 billion or 35.1 per cent was controlled by non-residents, and $9.8 billion of this was concentrated in the petroleum industry.

The petroleum industry (exploration, production, refining and distribution) is dominated by foreign controlled firms which account for over 91 per cent of the assets and over 95 per cent of the sales of the industry. About four-fifths of the non-resident controlled assets are held by U.S. interests.

The current level of foreign control in the coal industry is about 73 per cent and reflects recent developments in western export-oriented metallurgical coal development.

The uranium industry has a mix of public and private ownership, with over 20 per cent of the assets under foreign control.

The most important source of funds for the petroleum industry is internal cash generation. Internal sources of funds tend to account for an even larger proportion of the capital of the foreign controlled firms than of the Canadian controlled sector of the industry. For the period 1961-1970, 66 per cent of

the capital for the industry came from internal sources. Of the sources external to the firm, 35 per cent was drawn from Canadian sources. Approximately 23 per cent of total financing was derived from foreign sources.

Most territory which is expected to yield new oil and gas reserves is already under permit to firms doing exploration. Canadian-controlled firms only hold the rights to about 15 per cent of federal and provincial permits and leases.

The market dominance achieved by many of the foreign firms makes it difficult for smaller and newer firms to gain a foothold. The vertically integrated structure of the largest firms in the petroleum industry permits them a kind of flexibility of access to capital reserves to meet the large capital needs, which a less integrated Canadian firm would have great difficulty challenging. The National Oil Policy, which divides Canada into two marketing regions, has also affected the capacity of independent non-integrated firms to compete.

The desire of Canadians for rapid development, frequently beyond the immediate capacity or preparedness of Canadian firms to undertake, and the interest and capacity of foreign petroleum companies to undertake these projects have made for high levels of foreign control in this sector.

Foreign governments, especially the United States, have encouraged their companies to work outside the country through beneficial tax policies and Canadian governments have been receptive to such investment.

The Impact of Foreign Control

Because of the importance of the petroleum industry within the energy sector of the economy and the dominance of foreign control in that industry, the discussion focuses primarily on petroleum.

Foreign investment has and does involve advantages for Canada in the development of its energy resources. The development of activity and employment in these industries would likely not have been as rapid in its absence. Productivity might be advanced through access to superior technology and efficient management. However, Canada might not always be realizing the full potential benefits from energy investments—and this may be due in part to the high level of foreign control in some areas.

Foreign controlled operations could contribute more to Canadian economic activity if more goods and services were procured locally, if more R&D were done in Canada, and a greater degree of further processing were completed within the country. The international allocative process of the multinational enterprise may not be according Canada maximum opportunities in these respects. Prices set for non-arms-length transactions on large volumes of international trade can affect Canadian tax revenues. The structure of industry in Canada is also affected by the dominance of large foreign-controlled firms.

In terms of Canada's overall balance of payments and trade position, the oil and gas industry is an important factor.

> In 1970 oil and gas exports amounted to almost 6 per cent of total exports, while imports by this sector accounted for 4 per cent of total imports. These relative proportions have reversed from their 1965 levels, thereby reflecting the contribution of this sector to Canada's increasing trade surpluses.

In terms of importance, the impact on Canada's capital account is perhaps the largest. Of the total foreign direct investments in Canada in 1970, the oil and gas industry accounted for almost 30 per cent, while only accounting for 12 per cent of the outflow due to direct investment overseas. Taking all the transactions for the oil and gas industry on the capital account, the industry accounted for an average of 34 per cent of the balance in the years 1965-1969.

In the period 1965-1968, the sectoral balance of payments was in approximate balance with capital inflows offsetting the deficit on the current account. After 1968 the sectoral balance of payments began to show substantial surpluses which, by 1970, amounted to about $350 million due mostly to the sharply rising trade surplus resulting from crude oil export growth.

The significance of foreign control on these international transactions and payments positions is difficult to assess. The transactions involved are large but the adjustments posed for balance of payments by this industry would not appear to turn largely on the nationality of the owners. The heavy reliance on foreign direct investment in this sector would suggest that the general balance of payments trends and their timing would have been different in its absence.

Aside from the economic and industrial aspects of foreign control, there are other concerns relating to the impact of high levels of foreign control on Canada's ability to determine its own priorities, and to control its environment.

Existing Foreign Control Policies

Canada has a number of laws and regulations, at both provincial and federal levels, which influence the role of foreign-owned and controlled companies active in the energy industries. These include the proposed Foreign Investment Review Act; National Energy Board Act; functions of the Resource Management and Conservation Branch of the Department of Energy, Mines and Resources, and the Northern Economic Development Branch of the Department of Indian Affairs and Northern Resources; recent revisions of the Income Tax Act; restrictions relative to foreign ownership of uranium; and the Atomic Energy Control Act.

In addition, the federal government role in Panarctic Oils Ltd. is an example of a direct government initiative which furthers domestic ownership as does the establishment of the Canada Development Corporation by a special Act of Parliament to ". . . help develop and maintain strong Canadian-controlled and managed corporations in the private sector of the economy and . . . give Canadians greater opportunity to invest and participate in the economic development of Canada".

Future Options Regarding Foreign Control

Foreign investment is not the sole, nor perhaps the most important cause of any concerns related to Canada's realization of maximum benefits from the energy sector. Foreign direct investment does, however, involve a variety of potential costs and benefits for Canada. As a result, no single policy can be expected to remove all concerns relating to foreign investment in the energy industries.

Many of the elements of an energy policy would alter the mix and magnitude of the benefits which Canada realizes from foreign investment in this sector. Any further initiatives on the issue of foreign investment must furthermore be com-

patible with Canada's industrial goals, international objectives and objectives in federal-provincial relations.

Some of the "gaps" which exist in Canadian capacities to undertake some projects and that can therefore be considered as contributing factors in the level and nature of foreign investment, may best be dealt with through general economic or industrial policies.

Changes in general industrial and energy policies are not, however, able to influence some of the factors which affect international investment and the way it operates in Canada because some of these are rooted in institutions and policies outside of Canada. Furthermore, some general policy approaches may not permit the realization of the benefits of foreign investment while reducing its disadvantages.

A variety of policy approaches have been suggested in public discussions and should be tested as to their advantages and disadvantages in dealing with foreign investment in the energy sector. These include:

(a) Canadian participation in the equity of all firms—e.g. 51 per cent Canadian ownership in the equity of all energy companies, or of any new ventures.

(b) Joint ventures involving Canadian partners—public or private.

(c) Carried interest rights for a public authority leading to "participation" in the firms involved.

(d) Public ownership of a firm in this set of industries.

(e) More extensive use of a review procedure in the investment made in the energy sector.

Canadian Attitudes Towards Energy

Our attitudes towards energy are unique for a northern nation. We have chosen not to be frugal in our use of energy, but to use it liberally to enable us to develop life styles similar in many ways to those of warmer, more densely populated industrialized countries. We aspire to the benefits of both urban and rural living, with large living quarters with ample space around our homes, our cities occupy a much larger surface area than the cities with equivalent population in most other nations, we expect as a matter of course to have a high degree of personal mobility and local and long distance communication, and many Canadians enjoy at times the use of a summer cottage or a winter cabin. This attitude toward life takes for granted the availability of ample energy, and it uses large quantities of energy to overcome the problems associated with our rigorous climate, large land area, and relatively dispersed population. Our energy policies must take into account these attitudes and their economic and social implications.

A distinctive situation in Canadian life relates to the change of life pattern of native Indians and Eskimos consequent upon the introduction of a high-energy technology and its associated economic and social system. Much of the potential for future energy resources lies in areas where the life styles of native peoples could be strongly affected, but where development of energy resources offers the principal hope for economic prosperity in the near future. Energy policies will have important social and cultural, as well as economic and environmental consequences in the hinterland of Canada.

Energy and the Natural Environment

Most Canadians agree on the desirability of maintaining a clean and healthy natural environment. There is increasing concern about the deterioration of the quality of the environment in many parts of Canada. The production and use of energy have contributed to this deterioration. However, with adequate environmental awareness and knowledge, it is possible through selection and design of processes and equipment, and proper technology and operating procedures, to produce and use adequate energy for present and foreseeable future requirements, and at the same time improve the quality of the natural environment and maintain it at an acceptable level.

The cost of improving the quality of the environment where it has been adversely affected by energy activities, and of maintaining the quality in all parts of Canada at a level up to or above the acceptable national objectives, against undesired effects of energy activities while still producing and using energy in the amounts anticipated for the period 1974-1983, has been estimated to be in the range $7 billion to $10 billion. Such a cost would add 5 to 7 per cent to the estimated total cost of energy production and use during the decade. About two-thirds of the additional cost would be incurred in connection with the use of energy in transportation.

It therefore appears that the cost of environmental protection itself will not be likely to have an important effect on the national economy, or cause a significant change in the pattern of energy use.

Canada has an international responsibility to contribute to the solution of global environmental problems arising from the use of energy, and to finding ways for national needs for energy to be met without adding to the environmental problems of other nations or future generations.

Action needed to increase the effectiveness and economy of environmental protection and resource use while ensuring adequate energy for Canadians now and in the future includes:

—continuing review and revision of federal and provincial environmental regulations applicable to energy activities;

—research into Canadian environments and ecosystems and the effect on them of energy activities;

—research and development of methods of avoiding or lessening the undesired effects on the environment of energy activities;

—"before" and "after" studies of the environment in typical energy developments;

—the formulation and implementation of effective programs of land use and for use of aquatic and marine areas;

—identification of areas or environments of particular sensitivity to disturbance;

—public release of information on the environmental implications of the production and use of various forms of energy and various fuels;

—cooperation and exchange of information with industry and other countries on the environment and the effect of energy activities;

—the development and strengthening of effective international environmental law.

SECTION I

ENERGY IN CANADA

CHAPTER 1—Energy and the Quality of Life in Canada

CHAPTER 2—How Canada's Energy Industries Evolved

—A Quarter Century of Development
—The Energy Industries—What They Are
—Federal Energy Policies

Chapter 1

ENERGY AND THE QUALITY OF LIFE IN CANADA

The availability of energy, additional to that needed for biological and economic survival, and the way in which we use that energy, determines to a great degree those aspects of Canadian life that lead to satisfactory and improving quality. The life styles of Canadians, and their aspirations, have as a basis the second highest use of energy per capita of any nation.

Values and concepts of the quality of life are changing. But improvements in the quality of our lives are not likely to be accompanied by a reduction in the total use of energy. Nor will an increase of energy use automatically lead to improvement in the quality of life. It is important that the energy policies of Canada enable Canadians to have adequate energy for their needs, and facilitate its proper use to create a satisfactory and improving quality of life for all.

A fundamental objective of Canada's national energy policies is that they should enable the sum total of all activities connected with production and use of energy in Canada to lead to a better life for Canadians, now and in the future. Some aspects of the "better life" may be defined and quantified;—they relate to material standard of living, medical health, availability of education, etc. Other aspects, cannot easily be described, although they are vital to the satisfaction and self-esteem of every individual and to the cohesiveness and vigour of every society. These aspects are popularly referred to as the "quality of life", a term that defies precise definition, although it is a very real concept to each of us. Canada's energy policies will succeed to the extent they contribute to each Canadian's concept of an improvement in his quality of life.

Our perceptions of the quality of our lives are basically our personal interpretations of the circumstances in which we find ourselves, and of the options open to us. As such, they vary widely, according to our economic situations, our traditions, interests and abilities, and the constraints on our actions; and they are constantly changing, individually and collectively.

Quality of life has material, cultural, religious, and philosophical aspects. While the amenities of life may vary from place to place, and perceptions of quality of life vary from person to person and from culture to culture, each person, whether he be rich or poor, whether he be a city dweller or a country dweller, looks upon the quality of life he now enjoys as being capable of improvement. For all of us, an essential aspect of the quality of our lives is the opportunity and ability we have to improve that quality. Despite the subjective and personal nature of our perceptions of the quality of life, and the wide range of interpretations given to the concept,

some factors may be common to our individual and collective ideas of life of desirable and improving quality:

i) we must have available a *surplus of resources*, tangible and intangible, above those required for mere biological existence;

ii) we must have a *suitable natural and social environment* to which we can relate;

iii) we must have *freedom of choice among a range of options* for individual action;

iv) we may feel a need to be part of some *regulative or protective mechanism* so that our individual actions do not work to the detriment of society and we are not unduly disturbed by the actions of others;

v) we may share a conviction that *individual happiness does not result from material prosperity alone.*

To some extent each of these factors is influenced, directly or indirectly, by the availability and cost of energy. For Canadians in the 1970's the quality of life is related to the way we use our technology and energy to achieve goals beyond those bearing directly on biological and economic survival.

Changing Values

These goals, and thus the values by which we judge shortcomings or improvements in our quality of life, are changing. Basic concepts that have equated national progress and strength with increased industrialization and resource use and larger populations are being questioned. The view that Nature exists for the use of man, and that the wilderness is of no value unless put to human use is being replaced by an awareness that we are a part of Nature, that our long-term survival depends upon our fitting harmoniously into the ecosystem, and by a concern that some of our present activities may be damaging to the ecosystem and thus to us as a species.

New concepts of the quality of life have arisen from the changing values, which in turn are related to our technological, consumer-oriented life style and fundamental to all of them is the individual and corporate use of energy.

Energy and Life Habits in Canada

Because of the geography and climate of Canada, energy plays a proportionately larger role in our activities than it does in many other countries. We require a comparatively large amount of energy per capita to provide the food, shelter, clothing and communication needed to live in reasonable physical comfort. The activities and opportunities that enable us to fulfill our desires as well as our needs, will usually require energy additional to that needed to keep us fed and warm. Today an average Canadian's total energy use can be expressed as an equivalent of 55 barrels of oil per year. The United States per capita use is about 60 barrels.

Our climate, our thinly spread population, our available land space, our traditions and our relative technological sophistication, all tend to make the things we do by choice, rather than by necessity, rather high users of energy. It is this energy, disposable according to our discretion and our tastes, that enables us to have the

goods and services, the personal mobility and the communications that enrich our lives. It is this energy that can be used now, or at any time, to provide for future benefits;—to "undo" undesired man-made changes in the environment, or to manage and beautify our surroundings. Such energy is also available for us to use to our individual or common detriment as well as our good. Energy used to advantage by one man or interest group may adversely affect another.

Many of the essential ingredients of the quality of life are not related to material prosperity. Yet there is sometimes a tendency to consider that since the use of energy is closely related to material wealth, then the use of energy itself, or the employment of energy-consuming equipment, is detrimental to the quality of life. In this view, society's appetite for energy becomes not only an index of our industrial and domestic activity, but a symbol of the ills of society. From this attitude it is but a step to the thought that if the use of energy were controlled, many of society's ills would be lessened and the quality of life enhanced.

The fallacy of considering a high consumption of energy to be in conflict with a high quality of life is soon apparent. Those who propose a radical reduction in our use of energy in order to enrich the quality of our lives often emphasize the advantages of a simple life, and assume that such a life style would require less energy. Yet few Canadians would consider their quality of life enhanced if they lived a bucolic life the year round under our climatic conditions. For all twenty-two million Canadians to accomplish this, however fleetingly, would involve a great increase of travelling, and much industry-produced equipment to enable us to enjoy nature without destroying it, not to mention the environmental management services required. All of this would use a great deal of energy.

A man who paddles down a quiet woodland stream "under his own power" tends to forget that he drove to the stream in a 200-horsepower car whose engine used only one-quarter its energy to move a mass of which he was only a one-fifteenth part; that he sits in an aluminum or fiberglass canoe, produced through the expenditure of considerable energy and used, perhaps, only a few hundred hours in its total lifetime, although the materials are nearly indestructible; that he carries precision instruments like a camera and binoculars that are probably unnecessary to his existence but which required a great deal of energy in their manufacture; that every roll of film he exposes is a heavy consumer of energy in manufacture and processing, etc. He may overlook the fact that while in the woods he left his automatic furnace or humidifier on in his house, his refrigerator running and his porch light burning. In fact, his brief return to simple nature has been accomplished and made worthwhile through the expenditure of more industrial energy than most urban or industrial activities he could have chosen.

This example, and a thoughtful consideration of the many ways in which Canadians desire or are able to express their recreational, artistic, intellectual or social interests, suggests that in the modern Canadian context, a life of high quality is possible only if we have ample available energy. A reduction of energy use would in most cases lead not to a concentration on activities that are commonly accepted as contributing to the quality of life, but to emphasis on utilitarian activities, with individual choices likely restricted to those extra activities in which the use of energy is more nearly an end in itself.

Adequate energy is essential to a high quality of life. But an increase in use of energy will not necessarily lead to a higher quality of life. The quality of life may depend not only upon having a range of choices available, but upon having the ability to make choices with a proper perspective of immediate and long-term benefits. Such ability and perspective may be more difficult to develop and to exercise when surrounded by an excess of goods and available energy.

Regardless of whether they live in the city or in a frontier area, Canadians in the latter part of the twentieth century have evolved or are striving toward a life style that depends heavily on technology and on a high per capita consumption of materials and energy. Thus the extra wealth and freedom of choice and action that will enable us to turn a mundane existence into a worthwhile and satisfying life, will depend in large part on proper use of additional technology, materials and energy.

The use of energy, in amounts equal to any reasonable demand, is essential to the attainment of a high quality of life in Canada. It is indispensable to generate the wealth that will enable Canadians to improve their social environment, to protect and enhance their natural environment, and to produce the surplus of goods and services, the range of individual choices and actions, the opportunities for education and intellectual development, the leisure time and the bonds within our society that will enable each of us, according to our interests and values, and all of us together, to improve the quality as well as the prosperity of our living. Our energy policy must make this possible.

Chapter 2

HOW CANADA'S ENERGY INDUSTRIES EVOLVED

A Quarter Century of Development

The role of energy in Canada has grown dramatically over the past 25 years as a result of a combination of two major factors—technological developments worldwide, and evolving government policies. Government policy decisions have a major impact in influencing industry patterns.

While supply and demand have expanded, there have been major changes in the pattern of expansion with oil, gas and electricity rising strongly and coal and wood declining. Electricity is proving to be a preferred energy form with an increasing percentage of it being generated through the consumption of coal and oil. Nuclear generation of energy is still a minor factor.

Production of energy is a major business in Canada with its growth based on a doubling of use over the past 12 years and a strong export market. The energy industries have a major influence on Canada's international trade position, are responsible for a large part of total spending on capital expansion, have revolutionized the Prairie economy and have created new Canadian communities.

Adequate, reliable and reasonably-priced energy resources have proven vital to Canadian life. These are key considerations in considering the future of Canada and in determining appropriate policies.

In those industries which make up the Canadian energy complex, the past quarter century has seen major development as well as significant change in the pattern of supply and demand. How this occurred is a reflection of worldwide events and the impact of energy policies of governments in Canada.

Briefly, some of the more important technological forces making for change in energy supply and demand included:

Advancing technology in oil and gas exploration and pipeline transportation leading to a large domestic oil and gas producing industry for the supply of a major part of the total energy market in Canada from British Columbia to Ontario;

Major oil discoveries throughout the world and related world pricing and supply pattern changes were felt in the Eastern Canada energy market, as oil replaced coal;

Conversion of major coal markets to oil during the 1950's;

In the 1960's the start of the decline of the relative importance of hydroelectricity and the emergence of thermal power based extensively on coal.

Government policies at both the federal and provincial levels have strongly influenced the growth of each component of the energy economy—the oil, gas, coal, electric power, and uranium and nuclear industries.

Indicators of industrial expansion must be viewed and analysed with a knowledge of the close interrelationship between the decisions taken by industry management, which result in changes in industry status, and the underlying government policies. A growth statistic is meaningless unless the policy reason for the statistical change is understood. Conversely, the impact of policy cannot be assessed without careful appraisals of the changes that take place in industry performance and in energy supply and demand patterns.

The function of government has been expressed differently from one energy source to another, and differently over time. It has ranged over the spectrum from government ownership or control of all phases from raw material to consumption, as in the case of uranium, to a mere "keeping of the ring", the provision of the rules under which the private sector functions. Peacetime energy policies in Canada have never encompassed centralized planning with specified production goals, allocation of energy production as between competing fuels, or control of the end use of fuels.

The common factor of the role of government, at whatever level and whatever time, has been to try to provide a climate favourable to the growth of the energy industries. At the same time, the goal has been the provision of adequate energy in an economy in which competition between fuels, as among other uses for the consumer's dollar, is a primary determinant of the structure and pace of industrial development.

Our energy policies reflect the federal nature of our country and the related division of powers between the federal and provincial governments. They reflect the interests of various governments in the development of natural resources, in orderly marketing with provision for avoidance of waste and conservation of resources, and in protection of the public safety. They reflect the desire of governments to encourage scientific research and technological advance, in the interests of assuring adequate supplies of energy at reasonable costs. In some cases they have reflected the need for government to pick up the pieces when decline of an energy industry has left men and communities at a dead end. Policies have reflected the external influences which affect most Canadian economic activities, and perhaps to an unusual degree our activities in production, marketing and use of the various forms of energy.

The Pattern of Energy Supply and Demand in the Period 1945-1972

Since 1945, there has been an expansion of oil and gas and electricity demand and supply, and a contraction of demand for coal and wood. These trends are illustrated by Tables 1 and 2 showing the changing energy patterns in Canada.

Even without the impact of indigenous oil and gas production on Canadian demand, petroleum use almost doubled between 1945 and 1950. During the same period, the use of coal in total began to stagnate at a level achieved in 1945.

TABLE 1

PRIMARY ENERGY CONSUMPTION

(in Btu[1] 10^{12})

	1945	1950	1955	1960	1965	1970	1972[(e)]
Oil[2]	397	726	1,163	1,668	2,216	2,836	3,110
Gas	49	72	141	382	747	1,250	1,405
Coal	1,105	1,078	878	556	644	709	705
Hydro[3]	369	507	730	1,014	1,180	1,560	1,700
Wood	225	190	145	120	100	80	70
Nuclear[3]					1	10	70
Total	2,145	2,573	3,057	3,740	4,888	6,445	7,060

[1]Btu: British Thermal Unit—an amount of heat required to raise the temperature of one pound of water one degree Fahrenheit.

[2]Excludes non-fuel petroleum products.

[3]Input equivalent of 10,000 Btu's per kWh.

[(e)]estimated.

TABLE 2

PRIMARY ENERGY CONSUMPTION

(Percentages)

	1945	1950	1955	1960	1965	1970	1972[(e)]
Oil[1]	18.5	28.2	38.0	44.6	45.3	44.0	44.0
Gas	2.3	2.8	4.6	10.2	15.3	19.4	19.9
Coal	51.5	41.9	28.7	14.9	13.2	11.0	10.0
Hydro[2]	17.2	19.7	23.9	27.1	24.1	24.2	24.1
Wood	10.5	7.4	4.8	3.2	2.1	1.3	1.0
Nuclear[2]						0.1	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[(e)]estimated.

[1]Excludes non-fuel petroleum products.

[2]Input equivalent of 10,000 Btu's per kWh.

Table 3 shows the regional breakdown of energy consumption in 1970. Data for 1972 are not yet available.

Oil

The ascendancy of petroleum in the 1950's was a worldwide phenomenon. It was primarily based on new technology in the automated burner market for residential and commercial heating. In the industrial field, competitive forces led to the ready acceptance of fuel oil as a substitute for coal. The private automobile advanced the demand for petroleum, and the trucking sector made inroads in the overall transportation field. At the same time, the railroads converted much of their coal-using operations, first to heavy fuel oil and then in the mid-fifties to diesel fuel.

TABLE 3

PRIMARY ENERGY CONSUMPTION BY REGIONS, 1970
(in Btu's 10^{12})

	Oil[1]	Gas	Coal	Hydro[2]	Nuclear[2]	Total[3]
Atlantic	367	—	57	75	—	499
Quebec	869	52	32	692	—	1,645
Ontario	890	462	479	452	10	2,293
Manitoba	100	63	18	77	—	258
Saskatchewan	113	112	36	23	—	284
Alberta	200	385	74	12	—	671
British Columbia, Yukon and N.W.T.	297	176	13	229	—	715
CANADA	2,836	1,250	709	1,560	10	6,365

[1]Excludes non-fuel petroleum products.
[2]Input equivalent of 10,000 Btu's per kWh.
[3]Excludes wood, provincial data not available.

With the discovery of major oil and gas fields in Alberta and Saskatchewan, the drive commenced for markets for domestic crude oil, both in Canada and the United States. This development had a salutary effect, reducing prices of petroleum products which previously had been imported. The eastward expansion of the crude oil pipeline system to Superior, Wisconsin and later to Sarnia and Toronto established a new pricing point for western Canadian crude oil in competition with supplies from the United States.

In the 1950's U.S. domination of the world price began to wane. However, until the late 1950's Canadian wellhead prices were essentially determined by a Sarnia base point linked with U.S. mid-continent fields. The break of the U.S. with world crude oil prices occurred when the United States imposed its mandatory quota system on oil imports in 1959. Canadian oil in effect became subject to world price competition through delivery of offshore crude to Montreal.

With the imposition of United States quotas and an overabundant world crude oil supply, the expansionary phase for Canada's oil producing industry would have come to a near halt in 1962 without the adoption of the National Oil Policy in 1961. The policy in the ensuing years consolidated the gains made in the earlier period and encouraged the use of Canadian crude as far east as the Ottawa Valley and the expansion of exports within the limits of the United States quotas.

Natural Gas

The expansion of the natural gas industry, although dramatic in the 1960's, proceeded with difficulty. Markets had to be found in industrial areas far from the centres of production and natural gas was following on the heels of the conversion of energy markets to oil. In British Columbia, this meant that an export market was necessary to make gas supply an economic possibility. Canada was in a weak bargaining position as export sales were negotiated at that time. The buyer, the U.S. market, was able to obtain an attractive price. Expansion into eastern Canada

had to overcome even greater obstacles of distance. Supply to Montreal was undertaken to provide needed service to that centre and to augment the marketing area of Ontario in order to try to make the overall project more viable. However, inclusion of Montreal subsequently proved much less of a necessity in the economics of eastern transmission. When the National Oil Policy line was established along the Ottawa River, natural gas in Montreal, to the east of the line, was left in a marginally competitive position with imported fuel oil.

Prior to the construction of long distance pipelines, consumption of natural gas in Canada was highly localized in the general areas of production. In 1945, Alberta accounted for 83 per cent of total natural gas sales of 49 Bcf (billion cubic feet). Local supplies in Ontario were responsible for the bulk of the remaining sales. By 1972 natural gas consumption in Ontario accounted for one-half of 1,256 Bcf used in Canada. The most striking change in end use has been the increasing share consumed by the industrial sector. In 1972, industrial sales were over one-half of total sales compared with one-quarter in 1945.

Electricity

Between 1945 and 1972 Canadian domestic demand for electricity rose from 40,000 to 231,000 million kilowatt hours. The average annual growth increase of 6.7 per cent is far higher than the 4.3 per cent annual growth rate for gross energy consumption as a whole. The fastest growing demand during this period came from the residential/commercial sector of the economy which grew from a level of consumption of 1,840 million kilowatt hours in 1945 to an estimated 75,000 million kilowatt hours in 1972. The growth in the demand for electricity from the industrial sector has been much more modest, approximating the rate of growth in overall energy use by industry.

The changing supply pattern for electricity is of considerable significance. While the predominance of hydro power remains, thermal generation of electricity is resulting in increasing demand on Canada's fuel resources and on fuel imports. During the period 1945-1972, the contribution of hydro to total electricity generation dropped from 97.6 to 75.1 per cent while thermal generation rose from 2.4 to 22.1 per cent. In 1972 2.8 per cent was generated by nuclear power.

Coal

During the 1950's and most of the 1960's the displacement of coal in the residential and commercial markets, in the field of transportation, and as a boiler fuel in industry and by utilities, caused stagnation in the coal industry. When almost all railway transport needs were supplanted by oil, the market and production declines were particularly severe. Aid to an ailing coal mining industry through a subsidy program prolonged the adjustment period in some areas in Canada without really attacking the basic structural problems that confronted the industry.

Consumption of coal in Canada reached a peak in 1948. In that year 47 million short tons were used, compared with 29.8 million tons in 1972. After 1948 coal use in Canada declined at the rate of 3.5 per cent per year to a low point of

22 million tons in 1961. Declines were most marked in the transportation field, followed by residential and commercial use. Largely as a result of the increasing demand for coal in the steel industry for coke making, the industrial sector demand for coal has remained comparatively unchanged. Thermal electric power generation has accounted for steadily increasing and significant amounts of coal since 1961. The principal markets in Canada are now the thermal power and metallurgical markets. A remarkable growth in exports of Canadian coal to Japan has led to the recent revitalization of the coal producing industry in Alberta and British Columbia. Canada's 1969 output was almost doubled, to 20.1 million tons in 1972. Total demand for coal in Canada in 1972 was 29.8 million tons with imports being the equivalent of two-thirds of demand and being used mainly in thermal power generation.

Nuclear Energy

Nuclear energy has not yet made a significant impact on the energy market. The share held in 1972 was less than one per cent. However, the rapidly rising energy demand, coupled with advances that are being made in nuclear power technology, indicate that nuclear energy will be an important source in the future. Production of uranium oxide, mainly for export, reached a peak of 15,892 tons in 1959, declined to a low of 3,701 tons in 1968, and recovered to a level of 5,204 tons in 1972.

The Role of Energy in the Economy

The role played by energy in Canada becomes apparent even in a somewhat brief examination of the economic performance of those components which together make up the energy industries.

Energy production in Canada is a major industrial activity in itself. In 1972 the production of coal, petroleum, natural gas, natural gas by-products and uranium had a value of approximately $2.4 billion. The value of electrical energy produced by utilities for sale and by industries for their own use totalled $2.5 billion. Energy consumption doubled in the past 12 years and promises to continue to grow at a rapid though possibly decreasing rate. Domestic energy is becoming increasingly important as the overall energy base grows and the proportion of demand met by imports declines.

The magnitude of energy supply and demand, the progress towards self-sufficiency and subsequently to a net export position are important with regard to balance of trade considerations. While energy demand was doubling during the past 12 years, the deficit in energy trade of $300 million in 1960 changed to an estimated surplus of $634 million in 1972. Had there been no oil, gas or coal supply operations within Canada, the annual deficit in the energy trade account would by 1972 have been in the order of $2 billion. There are also numerous other international transactions associated with the energy sector which affect the balance of payments position of the country. Large international capital movements are associated with the energy industries. In addition, but of lesser significance from a balance of payments point of view are the payments associated with the machinery and services bought and sold over the border and the payments of dividends and interest on foreign capital invested in this sector. Since many of these transac-

tions are related to direct foreign investment in energy—particularly in petroleum—some additional consideration of this issue can be found in Section V of this report.

The indexes of real domestic product for all of the energy sources have considerably outpaced the growth in the total industrial index. On a 1961 base of 100, the total real domestic product index in 1972 was 180 whereas for petroleum and natural gas it was 310, and for coal it was 265.

The energy industries make some of their larger impacts on the economy through annual capital outlays for new plant and equipment. Capital investment in fuels and power facilities in 1970 was $3.2 billion in a total capital investment of $17.8 billion. Thus, investment in the fuel and power sector accounted for almost one fifth of total investment in new Canadian facilities. Capital expenditures in the electrical generation industry were one half of the energy industries' total, in the petroleum and natural gas industries, 47 per cent, with the remaining 3 per cent in coal and uranium.

The proportion of the consumer's dollar going to direct energy purchases, is about 7 to 8 cents. This is significant and illustrates the importance of ensuring the availability of energy at reasonable prices. Adding together total outlays for purchases of energy and of energy-using facilities, such as cars and home appliances, Canadians may be spending as much as one quarter of their disposable income for the purchase of energy requirements.

The total impact of energy producing and using activities on balance of payments, in addition to the trade effects, is of increasing importance in its implications for other policy concerns, such as foreign ownership and control. The current account includes considerable outward flow of interest, dividends and other payments, as well as shipping payments for oil imports. The capital accounts reflect major net inflows of both debt and equity funds for investment in energy resource development, producing and transportation facilities. Thus, both current and capital account trends are considerably influenced by the nature and scale of energy supply and demand activities and commitments.

The importance of the energy industries is further illustrated by their impact on regional development. The role of the oil and gas industries in transforming Alberta from an exclusively agricultural base to a more multi-industry economy is widely recognized. Over the past 25 years, revenues accruing to the Alberta Government from land fees and sales and from production royalties have exceeded $3.6 billion. Employment generated directly in the oil and gas industries and in service industries dependent on oil and gas has provided support for a considerably larger population in the western provinces than would otherwise have been the case. One analysis has suggested that this increase could be as high as 900,000 people.*

The new coal industry activities in eastern British Columbia and western Alberta are estimated to have an employment multiplier effect of close to five. East coast offshore oil and gas exploration is already benefitting the economies of the Atlantic Provinces, especially Nova Scotia, and current general developments and activities in the Northwest Territories and the far north are heavily

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* "Regional Employment and Income Effects of the Petroleum Industry in Alberta". E. J. Hanson.

dependent on oil and gas exploration activity in that region. While the uranium industry has led to the creation of new communities, federal government stockpiling programs and other assistance have been required to maintain the industry and the communities over the recent period of market slump. The energy industries are thus playing a major role in various regions of the country.

The importance of the energy industries is shown through their contribution to the country's output of goods and services, improvement in the balance of trade and payments, increased capital investment, employment, government revenues, and economic growth of the country as a whole and its several regions.

The importance of overall energy policy considerations can be illustrated by such issues as: the need for reliable and adequate supplies of low-cost energy; the proper balance between domestic and imported energy supplies; the allocation of Canadian energy sources to domestic and export markets. An examination of some of the characteristics of the individual energy industries themselves gives a further perspective and appreciation of what must be considered in determining energy policy.

The Energy Industries—What They Are

Canada's oil needs are likely to triple through the final thirty years of this century. Major discoveries are needed in frontier areas and the technology and economic costs of Athabasca tar sands oil have to be established. The main questions relate to ensuring eastern Canadian oil supply and policies toward exports. Although the industry is closely affected by international developments (and is controlled by international companies), a high degree of government regulation ensures that Canadian needs will be met.

Natural gas has enjoyed dynamic growth, tripling in size in a decade. This industry is at a crucial juncture where decisions will have to be made on whether exports are to grow. It is closely regulated to assure supplies for Canada. Frontier areas can provide new sources but prices will rise. Natural gas is a premium fuel and end uses will concentrate in premium areas such as home heating. Varied jurisdictions are involved in the regulation of the industry, and the Constitution must be considered in evolving policy as well as consumer and producer interests and environmental impacts.

Canada has extensive resources of coal, especially in the Rocky Mountains. Research is needed to determine how to best handle this coal. The industry has changed from a large number of small local companies to a few major firms and ownership is concentrating in the hands of U.S. interests. Big companies are necessary because large volume mining means low unit costs. It may be desirable to seek wider markets for western coal. Business today is concentrated on Japan. Ontario depends on the United States for its coal supplies because of low transportation costs. Coal will likely be the cheapest fuel for electric utilities on the Prairies. Prospects are excellent as the coal industry revives and rebuilds from a depressed period.

Uranium evolved through a boom, bust and rebuilding period to three producing mines today. Government stockpiling has been necessary in recent years but existing producers now have sales contracts stretching into the 1980's. About one-quarter of known low-cost reserves are under contract for

export. Production can be doubled if orders become available. Canadian uranium is barred from the U.S. market and exploration is at a standstill. Canada has developed extensive nuclear fuel fabrication facilities and other higher technology for treating uranium. A question is whether a uranium enrichment plant should be built. Canadian requirements for uranium for power generation will be met by natural uranium used in the CANDU reactor, now established as a successful method of producing power.

Electricity is a huge industry in Canada. Hydro accounts for 75 per cent of the power generated but by 1990 nuclear sources will probably supply 25 per cent. Provincial utilities jurisdiction predominate and most of the electricity is generated by Crown corporations. New high voltage direct current technology and greater use of nuclear energy are leading to increasing interconnections between provincial power systems.

The individual industries which together make up the Canadian industry that provides the nation's energy supply are oil, natural gas, coal, uranium and nuclear, and electric power.

How did these industries evolve through the past 25 years? What is their present condition? What is their role today in Canada? What factors influenced them in the past? What factors are present today and likely ahead? These, and many other questions, have to be considered as each segment of the energy industry is examined in the following somewhat abbreviated discussions of extremely complex fields.

The Oil Industry

The growth and present scale of oil supply and demand operations is indicated in Table 1:

TABLE 1

OIL SUPPLY AND DEMAND

(in thousands of barrels/day)

	1962	1972[e]
Domestic demand	938	1,589
Exports—crude oil	236	951
—products	16	193
Total demand	1,190	2,733
Production—crude oil	715	1,689
—gas plant LPG	16	130
Imports—crude oil	369	757
—products	83	142
Total supply	1,183	2,718
Inventory change	−7	−15

[e]—estimated.

These statistics show the strength of energy demand on the oil industry. Requirements for petroleum products have been growing at the annual rate of 5.5 per cent. Production has grown more rapidly at the average annual rate of 9 per cent. The result has been a four-fold increase in crude oil exports while imports only doubled. Crude oil exports first exceeded imports in 1969. The industry thereby moved into a position of self-sufficiency in oil supply, going from a trade deficit position of $174 million in 1962 to a trade surplus of $334 million in 1972.

The regional oil supply/demand situation in 1970 is given in Table 2.

TABLE 2

OIL SUPPLY AND DEMAND BY REGIONS, 1970
(in thousands of barrels/day)

	Production	Exports: Crude*	Exports: Products	Imports	Inter-provincial Transfers	Domestic Demand
Atlantic	—		4	187	−5	178
Quebec	—		14	538	−80	444
Ontario	3		24	23	+473	475
Manitoba	16	5	13	1	+53	52
Saskatchewan	249	78	6	—	−105	60
Alberta	1,131	574	5	—	−445	107
British Columbia, Yukon and N.W.T.	77	13	27	13	+100	150
CANADA	1,476	670	93	762	+ 9**	1,466

*Exports from province of origin.
**Increased inventory.

The oil industry's resource base is large but still far from being fully appraised. Production comes almost entirely from the four western provinces with Alberta accounting for about three-quarters of the country's total output. Proved reserves of crude oil and natural gas liquids remaining in 1972 were 9.7 billion barrels. The potential resource, yet to be proved, is considered to be many times this total. However, the ratio of proved reserves to annual production has declined from 24.5 in 1966 to 15 in 1972. During the same period the ratio in the United States has declined from 7.2 to 6.0. The large production increases in the past two or three years have resulted in a reduction in the shut-in* capacity of 50 per cent in the mid-1960's to a relatively small margin today. The resource base of Alberta is considered to be delineated and forecasts indicate a levelling off in this province's production by the late 1970's. The oil resource base of the other western provinces is even more limited. Thus exploration is now being concentrated in the frontier areas, particularly in the Mackenzie River Delta area, the Arctic Islands and the

*"Shut-in" capacity is the amount of unused production ability in drilled and completed oil wells. It can refer to wells that produce only part time, or to wells that are not produced at all. However the term does not imply that all of the surface equipment or pipelines are necessarily in place to handle the full production rate.

offshore areas of the Atlantic coast. Increased attention is being given in Alberta to developments in the Athabasca oil sands area, and to the possibility of production from known large reserves of heavy oil hitherto not economically recoverable.

Further growth in production, on the scale experienced in recent years, will depend on the success of exploration programs in the frontier areas, on the industry's ability to open up the oil sands and heavy oil reserves on a large scale, and on price and financing factors. Annual expenditures by industry in the search for, and production of oil and gas, doubled to $2.1 billion in the period 1966-1972 and industry reports cumulative expenditures of $18.3 billion for the period 1947-1972. Annual expenditures will have to increase as the frontier areas are opened up. However, how quickly frontier areas can become suppliers of oil still depends on further exploration successes to justify the capital necessary to find, produce and transport the oil. It also depends on the ability of the industry to harmonize its activities with often fragile environments, particularly in sensitive Arctic and offshore areas.

Canada's petroleum requirements are met in about equal proportions from indigenous sources and from imports even though production now exceeds domestic market demand. The division of the domestic market into two components—west and east of the Ottawa Valley—originated with the National Oil Policy of 1961 and has been maintained ever since. That part of Canada west of the line is substantially supplied by domestic oil and the area east of it relies on imports from foreign sources. This arrangement provided growth opportunities for Western Canada crude in the domestic market and in the adjacent relatively high-priced U.S. market while giving Quebec and Atlantic Provinces markets access to crude oil at prices lower than would have prevailed if Western Canada crude had been delivered to these provinces.

The principal resource development-marketing question for the future, which will require careful policy consideration, encompasses the source of oil supply for Eastern Canada and the extent to which exports can and should be increased. As oil resource development in the frontier area proceeds, the answer to this question will become clearer.

Pending development of frontier resources, the federal government instituted a program of crude oil export control in March, 1973 in view of the fact that the fast-growing export markets were threatening to deprive Ontario refineries of their crude oil supplies. Exports of natural gas, electricity and uranium have long been under control and the newly instituted licensing system for crude oil exports added an important dimension to the federal government's administration of energy supply and demand operations.

It is clear from the trend of events in oil supply and demand in recent years that careful appraisal of developments in the oil industry is required in order to establish and maintain appropriate oil policies. These policies must have regard to the past and prospective growth of domestic oil markets, costs of oil supply and product prices east and west of the Ottawa Valley line; pricing practices and consumer reactions; marketing and price effects on other industries that depend on oil supply, including the petrochemical industry; regional development impacts; environmental protection; and the overall question of security of oil supply.

The Canadian petroleum industry cannot be considered in isolation. Even though it is ninth in the world in crude oil production, eighth in refining capacity and seventh in market demand, it is not at present a significant factor in the world oil scene. Its resource potential, particularly of the Athabasca oil sands, might be considered to support some expectation of a bigger role. Canada's dependence on foreign oil for about half of its domestic supply makes it greatly dependent on continuity of oil supply on a world basis. The Canadian oil industry's continuing ability to meet supply commitments at reasonable prices is based not only on Canada-U.S. relationships, but also on international trends and developments. This is why recent price trends in the oil producing countries grouped together as the Organization of Petroleum Exporting Countries (OPEC) and the negotiations between these countries and the international oil companies are so important to Canada.

The Canadian oil industry is tied to international developments not only through supply and demand conditions but also by virtue of its structure. The oil industry in Canada consists of a small number of large oil companies, which are affiliates of international companies, and a relatively large number of smaller 'independent' companies. The five largest companies operating in Canada account for almost half of its oil production and over four-fifths of its refining capacity. They import over two-thirds of the crude and products brought into the country. There is a high degree of foreign ownership and control in the industry as a whole. Over four-fifths of exploration and production activities are in the hands of foreign companies and practically all of the refining capacity. Policies related to the oil industry in Canada must take account of international developments, to the close ties between the domestic industry and the large companies operating throughout the world, as well as to the circumstances relating to domestic resource development and marketing.

The Natural Gas Industry

The following tabulation provides a measure of the growth and scale of operation of the natural gas industry:

TABLE 3

NATURAL GAS SUPPLY AND DEMAND
(in billions of cubic feet/year)

	1962	1972[e]
Domestic demand	432	1,256
Exports	343	1,012
Total demand	775	2,268
Net production	894	2,467
Marketable pipeline gas	769	2,252
Imports	6	16
Total supply	775	2,268

[e]—estimated.

These statistics show a dynamic growth situation in which domestic demand and exports have increased three-fold over the period of ten years, representing an average annual increase of 11.5 per cent. The domestic market is supplied almost entirely from Canadian fields and exports constitute 45 per cent of total marketable gas, exactly the same percentage as in 1962.

The natural gas supply/demand picture in 1970 on a provincial basis is given in Table 4.

TABLE 4

NATURAL GAS SUPPLY AND DEMAND BY PROVINCES, 1970

(in billions of cubic feet/year)

	Marketable Production	Exports*	Imports	Inter-provincial Transfers	Domestic Demand
Quebec	—	—	—	+51	51
Ontario	17	—	11	+418	446
Manitoba	1	—	—	+60	61
Saskatchewan	54	—	—	+48	102
Alberta	1,496	616	—	−618	262
British Columbia	271	164	—	+15	122
CANADA	1,839	780	11	+26**	1,044

*Exports from province of origin.

**Increased inventory.

The resource base is large but, as in the case of crude oil, largely undefined. Proved reserves of marketable gas were 53 trillion cubic feet at the end of 1972. The potential is felt to be many times this total. The industry produces over four-fifths its supply from Alberta and the remainder from British Columbia, with minor amounts from Saskatchewan and Ontario. The large margin of spare capacity that existed in the early 1960's has been reduced as production has increased. Ratio of proved reserves to annual net production has accordingly declined from 39 in 1962 to 23 in 1972. During the same period, this "life index" measurement of natural gas reserves in the United States declined from 20 to 11.

Future Canadian requirements for natural gas are protected by a formula administered by the National Energy Board. The Board requires that an amount of gas equivalent to 25 times the forecast domestic market requirements four years into the future is set aside for Canada's use. After having regard to trends in the discovery of gas, and also providing for existing export commitments, any further surplus gas may be considered as available for export. This formula was reviewed in 1970 and a decision was taken to maintain it. Subsequently, export applications were rejected because established reserves were insufficient to allow for additional exports after provision was made for future Canadian requirements under terms of the formula.

If substantial new exports are to be permitted, after provision for supply of Canadian requirements and existing exports, the rate of discovery will have to be

substantially increased. Based on expected growth of the Canadian market, the annual reserve additions needed will increase from 2.8 trillion cubic feet a year in 1970 to perhaps almost double that amount in 1990. The fact that the historic growth rate has been 3.5 trillion cubic feet a year emphasizes the importance of large-scale discoveries in the frontier areas if the industry is to continue to expand and to supply a growing domestic need. It can be noted, too, that under the present formula, a pipeline from the Arctic can only be approved if a sufficient part of the reserves supporting the project are designated for the Canadian market in order to maintain the 25-year protection requirement.

The question of allocation of available resources to domestic and export markets emerged as a major concern in the late 1960's as it became evident that U.S. supply would not meet that country's demand much longer. Competition by U.S. companies for Canadian gas began to become intense and has led to upward pressures on wellhead prices in Canada.

Within Canada the delivered cost of natural gas is influenced to a considerable degree by the distance between the natural gas producing areas in western Canada and the main consuming areas in Ontario and Quebec. Prices of coal and fuel oil have undergone rapid increases recently due to a number of factors while gas prices, based on longer contractual terms and being subject to regulation, have remained relatively stable. This factor coupled with the use of gas for environmental reasons has heightened the demand.

Canada has now arrived at a juncture in the natural gas industry where the Canadian market from Vancouver to Montreal is receiving natural gas service and the total apparent surplus has been committed to export markets. All of the federal government policy objectives have been met in some measure. However, the future development of the Canadian natural gas industry will face a number of important problems.

Perhaps the greatest problem is to determine the best use of such gas reserves as may become available in Canada in relation to increasing demand in Canada and the growing supply deficiency in the United States. Then there is the question of the amount of protection to be afforded to Canadian requirements, the appropriate length of future export licences and the problem of ensuring that all producers have an equal opportunity to sell gas with none being required to provide a disproportionate amount of "locked-in" or reserved gas to protect future Canadian requirements.

As the natural gas industry enters a new phase of expansion based on production from distant frontier areas, the problems of price will become increasingly apparent. In view of the fact that natural gas is a premium fuel, the question of end-use control will also arise. It is quite possible that this source of energy will eventually be directed into higher grade uses. This process has already started in the United States.

Finally, the natural gas industry is at the centre of jurisdictional differences because it is a highly regulated industry. Each of the sectors of the industry is subject to provincial or federal regulation. Exploration and production operations in the provinces come under provincial jurisdiction. In the Territories and the offshore the jurisdiction is federal although the offshore jurisdiction remains in dispute. Gathering pipeline operations are under provincial regulation whereas interpro-

vincial and international transmission pipeline systems come under federal jurisdiction through the National Energy Board Act. Distribution activities are of a utility nature and come under provincial jurisdiction. Here again, pricing, and the rate of price increases, may be the central issue as the price objectives of the various jurisdictions may be different. The recent policy announcements of the Alberta Government concerning higher field prices for natural gas have caused concern in other provinces where the objective is to obtain energy at lowest possible costs. A national policy for natural gas must therefore have full regard to the needs of the producer and the consumer as to supply allocation and price as well as to the constitutional division of powers as between Canada and the provinces and existing law of the several jurisdictions.

The Coal Industry

Canadian coal production reached a peak of 19.1 million tons in 1950 and then steadily declined to a low of 10.2 million tons in 1962. Production remained in the range of 10 to 11 million tons during the 1960's but since 1969 there has been a marked revival of the industry as a result of increased exports of metallurgical coal to Japan.

TABLE 5

COAL AND COKE SUPPLY AND DEMAND

(in thousands of short tons)

	1962	1972
Domestic demand	22,515	26,710
Exports—coal	894	9,421
—coke	131	263
Total demand	23,542	36,394
Production	10,217	20,638
Imports—coal	12,322	18,569
—coke	233	777
Total supply	22,772	39,984
Inventory change	−770	3,590

The supply and demand situation for coal is not only characterized by a strong upsurge in exports since 1969 but also by a steady increase from 12.3 to 18.6 million tons in coal imports in the period 1962-1972. Ontario's coal requirements are supplied almost entirely by imports from the United States. The growth in imports reflects increasing demand by electric utilities for use in thermal power plants. The only other principal use is for coke making in steel plants. All other uses, such as for railways, ships' bunkers, and for manufacturing plants, continued the decline which had been initiated in the 1950's when coal began to lose out to oil and gas. In the export market, there are major opportunities, particularly in

Japan, for metallurgical coal. The rate of export growth will depend considerably on the ability of the Western Canada coal mining industry to meet production schedules and quality standards and to compete successfully with Australia.

Canada's coal resources are large with most of them located in Saskatchewan, Alberta and British Columbia. A recent geological assessment of the coal deposits in these three western provinces indicates the presence of 118 billion tons of which Saskatchewan possesses approximately 12 billion tons, Alberta 47 billion tons and British Columbia 59 billion tons.

The provincial supply/demand picture for coal in 1970 is given in Table 6.

TABLE 6

COAL SUPPLY AND DEMAND BY PROVINCES, 1970
(in thousands of short tons)

	Production	Exports	Imports	Inter-provincial Transfers* Inventory Change	Domestic Demand
Newfoundland	—	—	2	+16	18
Prince Edward Island	—	—	—	+15	15
Nova Scotia	2,122	61	376	−642	1,795
New Brunswick	396	130	2	+75	343
Quebec	—	45	753	+542	1,250
Ontario	—	121	18,593	+40	18,512
Manitoba	—	10	9	+1,121	1,120
Saskatchewan	3,819	4	5	−1,335	2,485
Alberta	6,784	2,406*	—	−607	3,771
British Columbia & Yukon	3,483	1,927	4	−1,071	489
CANADA	16,604	4,704	19,744	1,846**	29,798

*Exports from province of origin.
**Increased inventory.

While the country's coal resources are very large and adequate for hundreds of years, much more information must be obtained on the quality of the coal and its mineability. The adequate evaluation of our coal resource is made difficult by geological conditions of the Prairie regions of Alberta and Saskatchewan and of the Rocky Mountains. Resource appraisals are now being made by the federal Department of Energy, Mines and Resources, in cooperation with the provinces. A more precise measurement of available coal resources can be expected within a few years. This assessment will provide information for future export policy formulation and will assist in determining the best end use of a given body of coal, whether it be for steam or for metallurgical purposes.

The structure of the coal industry has changed considerably in recent years. In the Maritimes the industry is under government management. Control of the

rest of the Canadian coal industry is in relatively few hands. Currently, eight companies produce about 90 per cent of the coal in Western Canada and four of these companies are U.S. controlled. Formerly the industry included many small operators based on local coal sales. With the present concentration on a few large and distant markets, only large companies can operate. Large volume production is required to achieve low unit costs. The capital, quality of management, and marketing expertise necessary can be marshalled only by large companies.

A further characteristic of the Canadian coal industry is its great dependence on efficient, reasonably priced bulk transportation because of the long distances between the mines and the markets in North America and overseas. A start had been made by 1970 in the use of a unit train system for the westward haul from the mountain mines of Alberta and British Columbia to Vancouver. However, there are no such transportation facilities running east and south to supply Canada's central markets or for exploiting the adjacent markets of the United States because this mode of transportation has not yet been shown to be economic to these markets. Furthermore, all Canadian coal exports overseas move in foreign vessels and Canadian participation in this growing transport activity has not yet been achieved.

In production costs, the strip mines of Saskatchewan and Alberta are among the world's lowest. The surface mines in the mountain coal fields compare very favourably with similar operations in other countries. For underground mining, Canadian costs are lower than all other countries except the United States, Australia and South Africa. Generally speaking, costs at Canadian coal mines, particularly throughout Western Canada, can be fully competitive on a worldwide scale.

In the international market, Canada finds competition from the metallurgical coals produced in the United States, Australia, South Africa, Poland and the Soviet Union. These five countries and Canada are the principal world sources with the capability for producing metallurgical coal in quantity and at internationally competitive prices.

The price obtained for coal used for steam raising purposes is generally too low to warrant international traffic and such coals are normally consumed within the country of production. In Canada, as in most countries, the chief steam raising market is the electrical utility industry and coal is used extensively in this market in Ontario, Alberta and Saskatchewan, and to a lesser extent in Manitoba, Nova Scotia and New Brunswick. In the Maritimes, utilities serve as a local outlet for coals produced under government rationalization programs. Because of high production costs and the severe competition from imported fuel oil, this coal has been sold at a loss. In Ontario and on the Prairies, coal is competitive with other energy sources. The Ontario utility market is almost wholly supplied by American coal. Provided the economics of large-scale transportation can be realized and production costs held down, western Canadian coals may eventually enter this market. On the Prairies, local coal is the cheapest fuel available and all indications are that it will continue to be the main source of energy for the utility market in the three provinces. For the future, the electric utility industry throughout Canada will be fueled largely by coal and uranium and, to a smaller extent, with fuel oil. Over the longer term, coal may find a large, new market involving its conversion to liquid and gaseous fuels.

Canada's coal policies will be concerned more and more with a number of specific problems and issues. These include the ownership of the industry which is rapidly becoming concentrated in relatively few hands, with a trend towards growing control by U.S. interests. There is also a growing trend for investment in the coal industry by the international oil companies and the same trend is appearing in the uranium industry. Another problem relates to the fact that most of Canada's capability for producing coal is being absorbed by Japanese interests on a long-term, large-volume commitment. While this is a valuable outlet for Canadian coal, a wider market may be advisable so that the fortunes of the industry are not so dependent upon changing conditions within one country. Domestically, the large Ontario market for both metallurgical and steam raising coal remains dependent on the United States. With the increasing costs of coal production in that country, domestic supply of some part of the Ontario market becomes an increasingly attractive prospect.

Through the rapid increase in production in Western Canada of recent years, a number of serious problems in the extraction and processing of coal have arisen. These problems point to the need for increased research if production objectives are to be maintained. Finally, with the Western Canada industry having good prospects for growth, notwithstanding a number of problems, it would seem timely to examine the overall return to the economy to ensure that adequate benefits are being received from the production and use of this non-renewable resource.

The Uranium and Nuclear Energy Industries

The Canadian uranium industry had its origin in the 1930's and operated as a wartime industry during the first half of the 1940's in order to meet the uranium requirements of military programs of the United States and Britain. In 1947 the ban on private exploration and mining was lifted and various incentives, including a guaranteed price for uranium, were offered by the federal government in order to supply uranium abroad. Under these conditions, the search for uranium flourished and by 1953 several large, low-grade deposits of uranium had been discovered. Most of these deposits were subsequently developed and by 1959, 23 mines with 19 treatment plants were in operation. In that year, the uranium industry reached its peak output and uranium ranked fourth in value among Canada's exports following newsprint, wheat and lumber.

However, it then became evident to the United States and Britain that sufficient uranium had been contracted to meet their foreseeable requirements and all their options to purchase Canadian uranium beyond March 31, 1963, with one exception, were dropped. To prevent a complete collapse of the industry, arrangements were made for the deferrment of deliveries and for the transfer of contracts. The federal government encouraged producers to arrange further sales, for peaceful purposes, on their own behalf. Despite these steps, the industry declined dramatically and, in an effort to retain a nucleus of production, the federal government established two successive uranium stockpiling programs with the second completed on June 30, 1970. Beginning on January 1, 1971, a joint stockpiling program between one of the uranium companies and the Government of Canada was commenced. This last program will terminate in 1974.

There are only three producers of uranium in Canada. Two of these are private companies, Denison Mines Ltd. and Rio Algom Mines Ltd. which operate in the Elliot Lake area of Ontario, and the third is the Crown company, Eldorado Nuclear Ltd. which is in production near Uranium City, Saskatchewan and also operating Canada's only uranium refinery at Port Hope, Ontario. A fourth potential producer is establishing a facility in northern Saskatchewan which is to begin operations in 1975.

The era of commercial uranium sales began for Canadian producers in 1966 and several commitments extending into the 1980's were made. In early 1973 there remained to be delivered under these contracts some 60,000 tons of uranium oxide, largely for export markets in Japan, Britain, West Germany and Spain.

During the 1950's and 1960's an important facet of the Canadian uranium industry evolved, nuclear fuel fabrication. Assisted by Atomic Energy of Canada Limited, as part of its mandate to develop nuclear power, two companies have developed an impressive capability in this area. Although the Canadian fuels fabrication facilities were primarily developed to supply fuels for Canadian heavy water reactors, they are also capable of competitively fabricating other types of nuclear fuel.

The Crown company, Eldorado Nuclear Limited, converts "yellowcake" from the mills of Canadian mines into several nuclear grade uranium products. Because the majority of nuclear reactors in the world use enriched uranium, and the demand for this product is increasing, Eldorado began in 1970 to operate a new plant to produce uranium hexafluoride. This is the feed material to produce enriched uranium. The refinery also produces a number of advanced reactor fuels and processes highly enriched uranium dioxide and uranium metal alloys.

At present, there is little concern about the adequacy of uranium resources in Canada although about one-quarter of presently known low-cost reserves are under contract for export. A modest recovery in uranium production since the low point of 1968 would appear to mark the start of a second expansion period for the Canadian industry. However, in view of the fact that world production in 1972 was under 30,000 tons of uranium oxide, and the demand forecast for 1980 is in excess of 70,000 tons, the recent expansion of uranium production in Canada, and in the several other major world producers, has been relatively small. Exploration in Canada is at a standstill due to the relatively poor sales prospects in the near term and the uncertainties concerning the application of the foreign ownership policy announced in March, 1970. In expectation of increased markets in the late 1970's, the industry has expansion plans that could more than double its productive capability.

In addition to the problems and uncertainties related to resource development and production, there is the question of whether Canada should be involved in uranium enrichment to improve its marketing prospects. Most of the world's nuclear reactors require enriched uranium and this is now available essentially from only one source, the United States. The CANDU-type of reactor, developed by Atomic Energy of Canada Limited, and now successfully operating at Pickering, Ontario, does not require enriched uranium. Consequently, enriched uranium will probably not be needed for nuclear power generation in Canada. However, because of the magnitude of our uranium resources, the availability of remote

hydroelectric power sites, and the close relationship with the United States from whom the technology of the gaseous diffusion process could be obtained, there is the possibility that an enrichment facility could be built in Canada. Problems in the establishment of such a facility include the tremendous cost, estimated at over $1.5 billion, and the possible conditions attached to the release of the technology. There is always the possibility that the development of advanced technology for enrichment may make the present technology obsolete before costs are fully realized. The question of whether Canada should embark on a uranium enrichment program remains to be settled.

In international trade, the embargo maintained by the United States on the use of foreign uranium in its domestic reactors remains a bar to the Canadian expansion in this market, which is the largest single national market for uranium. Other international marketing problems arise from the fact that other countries can compete successfully at lower prices because of the nature of their uranium deposits.

While the history of the uranium producing industry has been one of wartime activity, rapid expansion and a boom period in the 1950's, decline and stagnation in the 1960's, and a difficult revival in the early 1970's, the program of nuclear research and development has proceeded slowly but steadily. The CANDU reactor has been established successfully and is now beginning to attract world attention. It is a heavy water moderated reactor, fueled with natural uranium. For almost twenty years, the Canadian nuclear research and development effort has been directed to the objective of economic nuclear electric power. This objective has now been achieved. The Crown corporation responsible for this program, Atomic Energy of Canada Limited, administers assets of $500 million and, throughout its existence, has directed a program of research and development approaching $1 billion.

The federal government's nuclear energy program is now moving through the advanced developmental stages into the operation stage in which the provinces are assisted in establishing their own nuclear reactors and power plants. The Pickering plant in operation near Toronto is performing with outstanding success and assistance is being given to Quebec in the establishment of a nuclear power plant in that province. In addition, a major commercial sale of a CANDU reactor to Argentina has recently been announced.

The Electric Power Industry

Of the total electrical energy currently being produced in Canada, 75 per cent is from hydro sources, 15 per cent from coal, 4 per cent from oil, 3 per cent from natural gas, and almost 3 per cent from nuclear energy. Nuclear power generation will soon be supplying an increasing portion of electrical energy requirements.

The electric power industry is one of Canada's largest industrial complexes. At the end of 1970 the total assets of the utilities were $14.6 billion, and the total annual operating revenue was $2.3 billion.

Most major Canadian utilities are interconnected with neighbouring Canadian and United States utilities and share in the benefits of agreements for emergency energy supply, economic energy exchanges, and other types of power transfer. During the period 1965 to 1971, exports of electrical energy gradually increased

from 3,570 million kilowatt hours to 6,986 million kilowatt hours. In 1972 exports totalled 10,372 million kilowatt hours. During the period 1965 to 1972, imports were in the range of 2,000 to 4,000 million kilowatt hours. Over this period the net export of electrical energy increased from 0.1 per cent to 3.3 per cent of total electrical generation, a relatively small amount in volume but important in terms of mutual benefits to be gained through interconnected systems.

The supply/demand situation in 1970, by province, is given in Table 7.

TABLE 7

ELECTRICITY SUPPLY AND DEMAND BY PROVINCES, 1970
(in millions of kWh)

	Domestic Demand	Exports*	Imports*	Generation	Transfer
Newfoundland	4,737	—	—	4,821	−84
Prince Edward Island	250	—	—	250	—
Nova Scotia	3,652	—	—	3,457	195
New Brunswick	4,198	757	45	5,118	−208
Quebec	69,639	51	1	75,787	−6,098
Ontario	69,466	3,598	2,866	63,834	6,364
Manitoba	8,753	294	3	8,434	610
Saskatchewan	5,212	—	—	5,989	−777
Alberta	9,798	—	1	9,953	−156
British Columbia	25,150	896	278	25,614	154
Yukon and N.W.T.	490	—	—	490	—
CANADA	201,345	5,596	3,194	203,747	—

* Export from and import to, the indicated province.

Electric power systems are planned and operated as integral combinations of different types of generating stations linked by a transmission network to meet the varying load pattern in the most economic manner. Costs are related to this overall operation and not directly to the cost of power from any individual unit of the system. In contrast to the early days of the electric power industry, export applications now deal increasingly with power exchanges and short-term transactions since Canadian systems can generally absorb the output from new generating sources within a relatively short period. Exports of electric power are regulated by the National Energy Board, to ensure that only that which is surplus to Canadian needs is exported and that such sales are at a just and reasonable price.

Electric power plants and transmission lines are considered as local works and undertakings coming within the jurisdiction of the provinces. The industrial structure and the fact of provincial jurisdiction have produced close liaison between provincial governments and the electric utilities, many of which are provincially owned Crown corporations. The Peace River development in British Columbia, the Nelson River hydro development in Manitoba, the Ontario Government's en-

couragement of the nuclear generation program with its participation in the Pickering nuclear plant, Hydro-Quebec's purchase of Churchill Falls power and Quebec's decision to proceed with the James Bay power development are all examples of provincially sponsored and administered power development programs.

The large demands for capital goods by the electric power industry places considerable weight on the degree to which domestic manufacturers are able to participate in meeting these needs and thereby maintain a viable industry supply structure. The continued economic viability of the domestic manufacturing industry is sometimes threatened by various pricing and concession financing policies of foreign suppliers. Decisions to purchase equipment from domestic or offshore suppliers may have an important impact on Canada's total economic development beyond the regional considerations which the purchasing utility can be expected to evaluate.

The environmental consequences of the rapidly expanding requirement for electricity is an important consideration. However, pre-project environmental assessment used as a basis for environmental design or the development of a viable alternative can protect or improve the natural environment and the renewable resource.

The aforementioned considerations and the identification of the necessary technology to meet expansion requirements, are the key elements for effective future planning. Careful evaluation of the risks of delays in adopting new technology or, conversely, of premature adoption, is a difficult, yet essential, task—made even more difficult by the need to fully consider overall financial and economic factors important to Canada.

The key part which generation of power from nuclear fuels will play in the future should be recognized in any assessment of the present status of the electric power industry. Although hydroelectric plants presently produce about three-quarters of Canada's electric energy needs, the favourable sites located near load centres have now been developed. It is increasingly difficult for the remote hydro sites to compete with thermal generation at the load centre because of the burden of relatively costly long-distance transmission. As Canada's nuclear power program progresses, more and more of the country's electrical energy requirements will be produced in nuclear plants. The present forecast is that by the year 1990, nuclear energy will be supplying about 70 per cent of Ontario's electrical energy requirements and over one-quarter of the Canadian total. Paralleling this development there is likely to be an increase in the interconnections between provincial power systems, made possible by the advance in high voltage direct current technology. Thus, there is now a significant trend towards a linking of provincial power systems which more and more will be based on nuclear energy while hydroelectric plants will play an increasing part in providing peaking generation to meet daily and seasonal fluctuations in demand. While coal and oil will remain important as energy sources in thermal power plants, the present trend towards their increasing use in this respect, and towards greater reliance on imports of these fuels, will be reversed as more nuclear power plants come on stream. At the same time, the use of natural gas in thermal power plants will likely be phased out.

Federal Energy Policies

The framework of federal government energy policies is complex and adapted to constantly changing conditions. A periodic overall assessment and review is necessary keeping in mind a series of basic objectives. These cover availability at reasonable prices, encouragement of a proper rate of development, national security, export of surpluses and purchases from abroad, and achievement of already-defined national goals of Canadian ownership, control and environmental protection.

Each branch of the industry has policies designed for its special conditions at any given time. Uranium and coal have been helped during periods of difficulty and a major policy assures peaceful use of Canadian uranium. Oil and gas exploration was encouraged in the far north by establishing Panarctic. Many of the policies are outlined in this chapter.

The best complementary set of federal and provincial policies embraces electricity. Oil and gas represent difficult problems where the interests of producing provinces are different from the interests of consuming provinces. Uranium is an area where aspirations and policies of the provinces and the federal government overlap. The continuing task is to develop a consensus which will serve the best interests of Canada.

Energy in Canada has been moulded by detailed policies to meet the uniqueness of Canadian conditions and needs. Our policies relating to energy are complex, various and incapable of simple formulation. A simplistic label such as a "national energy policy" fails to identify properly even the more important policies working today or what may be needed for the future.

There is a framework of energy policies in place and operating. It has grown up over time, and in response to diverse stimuli. As does any historic accumulation of policies, from time to time it needs review, re-assessment and revision. While such revision may and should produce a set of policies that are coherent and relevant to the circumstances of the present and the perceptible future, it will have to involve a set of policies rather than a single policy. The energy industries and the public interests affected by them are too diverse to be expressed in unitary form, but periodically it is necessary to bring them within comprehension, and to assess those problems for which policies may need to be either re-affirmed, altered, or newly devised.

Energy policy administration has proceeded initially on the basis of the Canadian tradition of the free market system. The forces of supply and demand are relied on to a considerable degree. Where market forces alone have proved to be inadequate to serve and safeguard the overall public interest, varying degrees of government influence have been applied through polices and procedures formulated to meet specific national needs. These responses to specific situations have been designed to reconcile conflicting goals of various regional, provincial and industrial interests.

There are certain basic objectives running like a thread through the range of federal energy policies:

To ensure the availability to Canadian consumers of a variety of competing energy supplies at prices which are reasonable for both the consumer and the producer.

To encourage the development of our abundantly occurring national resources through the provision of fiscal and other incentives.

To safeguard national security, both in terms of the physical availability of resources, and the capacity to transport and use them.

To permit the disposal of surplus supplies in export markets, thus improving the country's international trade accounts and at the same time providing the domestic market with the benefit of scale.

To allow the acquisition of energy supplies from abroad, where these are more economic than domestic supplies, provided that such imports do not unduly inhibit Canadian development or present a serious security risk.

Finally, to achieve certain social and national objectives including the greatest practical degree of Canadian ownership and control of our resources and of the means of production, transportation and distribution, and protecting or enhancing the quality of the natural environment, and the maintenance or enhancement of the productivity of ecosystems.

Here is a summary of the more important policies and how they have helped shape the destiny of the energy industries.

Oil

Discovery of oil at Leduc in 1947 was followed by rapid resource development and the marketing of Western Canada oil as far east as Ontario and in central and western areas of the adjacent states. This rapid growth raised problems. In 1957 policy questions of resource allocation and of pipeline regulation were referred to the Royal Commission on Energy. Its findings led to the creation in 1959 of the National Energy Board. From the sequence of events in the dynamic decade of the 1950's, in which rapid growth was the principal characteristic, the necessary period of adjustment that followed was made possible by the establishment in February, 1961 of the National Oil Policy. This policy was designed to give western Canada oil full market access west of the "Ottawa Valley line" and to encourage its export to adjacent areas of the United States. Areas east of the Ottawa Valley continued to be supplied from world oil sources at international prices which have continued to be lower than those from Western Canada. The National Oil Policy was thus designed to achieve the resource development objective by providing marketing opportunities in a time of resource abundance without excessive penalty to Canadian consumers. (The actual policy statement is contained in Appendix C.).

Under the umbrella of the National Oil Policy of 1961, Canada's oil production grew steadily and by the end of the decade exports began to exceed imports. Although this satisfactory state of self-sufficiency was reached on the basis of a voluntary policy, the government in 1971 found it necessary to introduce licensing procedures for imports of gasoline. In 1972 events in the international oil economy were such as to raise questions on the security of supply. At the same time, United States market demand for Canadian oil, which had been controlled by U.S. policy in the 1960's, began to increase more rapidly. With frontier oil production in Canada not likely to be a significant factor in supply before the mid-1980's, Canada has now reached a point where new policy directions are required embracing allocation of markets for its existing oil reserves and a rate of development of its oil

potential in northern and offshore areas and in the Athabasca tar sands. To ensure the adequacy of oil supply to domestic refineries served by Canadian oil, pending the development of frontier resources, a system of export controls was instituted in March, 1973 (*see* Appendix C). A new policy direction in oil marketing was thereby added to the National Oil Policy concept of 1961.

Natural Gas

Natural gas policy prohibits the export of gas unless the quantities proposed for export are surplus to foreseeable Canadian requirements. This principle was embodied in the Exportation of Power and Fluids and the Importation of Gas Act of 1907 and has been adhered to ever since. Until the discovery of large quantities of natural gas, commencing in the late 1950's, this policy presented no problem but as reserves built up the question of market allocation became the subject of much public debate.

Natural gas marketing policy in the 1950's was implemented in terms of decisions taken in respect to three principal events. During the Korean War, gas export to an industrial area in Montana was permitted. In the mid-1950's, Westcoast Transmission Company Limited was given permission to export gas from northeastern British Columbia into the State of Washington in order that its pipeline project, which required a greater throughput than could be marketed at the time in Canada, would be viable. Later in the 1950's TransCanada PipeLines Limited was given Ministerial assurance that gas export would be permitted as part of a project developed by private enterprise to supply markets in Ontario and Quebec via a Canadian route, provided certain commitments were undertaken including the assurance that the principal gas supplies would continue to move over the Canadian route. This policy of an all-Canadian route provided a significant stimulus to industrial development, particularly in northern Ontario, and the economics of the project were improved through the export provision.

These three export decisions confirmed a natural gas policy which permitted export only to the extent that supplies, surplus to reasonably foreseeable Canadian requirements, were available, and for time periods long enough to support the necessary pipeline investments. It also required that suitable export price arrangements were made. Administration of this policy came under the National Energy Board Act of 1959. While a number of export projects were approved in the 1960's on the basis of surplus requirements, in 1970 a project for a new export pipeline was refused an export licence and other applications were approved for shorter times and smaller quantities than those sought by the sponsors. In 1971 another group of export licence applications was dismissed because reserves surplus to Canadian requirements could not be demonstrated. In 1970 a condition was imposed on certain export licenses to require that the export price be 105 per cent of the existing rate in the areas of Canada where the gas crossed the international border.

As in the case of oil, new policy directions are now needed to direct the rate of frontier resource development in view of the strong demands of the domestic and export markets on existing Canadian resources, and also because market price differentials are emerging.

Oil and Gas

Government procedures for the disposition of mineral rights on federal lands, under the Canada Oil and Gas Land Regulations, and for the orderly development and production of oil and gas, under the Oil and Gas Production and Conservation Act, are also expressions of oil and gas policy. There are numerous laws and regulations at various levels of government relating to transportation, refinery operations, marketing procedures, safety and labour relations. Government involvement in Panarctic Oils Ltd. is a unique example of resource development policy in this country in that one of the major considerations was to maintain exploration activities in the north, and to keep the smaller Canadian independent companies involved. Finally, there are very important fiscal policies applying to oil and gas which serve to encourage resource development through tax provisions relating to depletion, exploration costs and depreciation.

Coal

Canada's coal policy has been identified for many years with various forms of support. The most prominent support was the system of transportation subventions which was phased out in 1971 after over 40 years of application. Subventions were made available in order to prevent or alleviate social problems arising from growing unemployment in coal mining areas. This coal policy was thus highly regionally-oriented. A subvention and loan program in the 1960's helped the western Canada coal industry to develop new markets in Japan and thus to move into a new stage of expansion.

Alternate assistance is now being provided to the Nova Scotia coal industry through the Cape Breton Development Corporation, a federal Crown agency, whose objectives are to phase out the uneconomic mines and develop economically viable industries in Cape Breton. The rationalization of the New Brunswick coal mining industry has been assisted by a five-year program of federal grants to the New Brunswick Government in lieu of a continuing subvention program.

While a number of technical problems relative to production, bulk transportation and environmental controls remain to be resolved, the coal industry, with its huge resource base, appears to be heading into an era in which it will make increasing contributions to the energy requirements of the country, and to national earnings through exports to other countries. However, the long distances between our major coal producing areas and the large Ontario market still result in major imports of United States coal for both metallurgical and power generation purposes. This import reliance has security of supply and balance of payments implications.

Electric Power

The Exportation of Power and Fluids and Importation of Gas Act of 1907 stopped the development of a pattern of long contractual export commitments of up to 99 years, and instituted a requirement for annual review of both volume and price. The policy was again changed in 1959 with the passing of the National Energy Board Act which provides for exports under licence for periods up to 25 years after due allowance is made for reasonably foreseeable requirements for use in Canada.

The liberalization of policy so introduced was closely associated with the contractual practices developed by the electrical utilities, reflecting the availability of power from a number of sources through interconnected operations. The recovery of power under such arrangements had lessened Canadian fears regarding repatriation of power exports. A further step was taken in 1963 when the general principles of the federal government's electrical power policy were announced and included the fostering of international connections and of a nationwide power grid (*see* Appendix C). This policy provided that special arrangements might be approved for exports considered to be essential to the economic viability of large-scale hydro development projects.

Electric power policy is further evidenced through the federal government's sponsorship and coordination of the design and construction of the high-voltage direct-current transmission system from the Nelson River to southern Manitoba, and assistance to interprovincial inter-ties in the Atlantic Provinces. Furthermore, the federal government has provided a $17.5 million loan for the construction of the Hydro-Quebec Institute of Research plus an annual grant of some $300,000. The research work of this Institute is directed to national need, especially in high voltage and high power work.

Uranium and Nuclear Energy

A Crown agency was established during World War II to develop uranium resources for strategic purposes. During the 1950's industry joined in the development of these resources and production grew rapidly. But with the sudden end of United States and U.K. purchase contracts in 1959, the Canadian industry entered a severe period of retrenchment and the policies that prevailed during the boom period of the 1950's had to be drastically revised.

Because of the strategic nature of uranium, ownership and related policies affecting this energy source have been unique. In the earliest period of this industry, the federal government concluded that the industry must not only be owned by Canadians, but that the government should, in fact, operate the property and plant. After World War II, the federal government remained the sole purchaser of uranium, although private enterprise was allowed to participate in exploration and production of uranium. In the 1960's, following the loss of the U.S. and U.K. markets, the government assisted the industry by negotiations with customers, by arranging transfers of contract commitments, and by instituting a stockpiling program. This program was justified on the grounds that the new large mining communities had been established in isolated areas, partly with government assistance, and although the immediate uranium demand was small, the future prospects were considered to be good. Throughout all resource development and marketing activities since World War II, a Crown company, now called Eldorado Nuclear Limited, has served as an important policy instrument of the federal government.

All export sales of uranium must be approved by the Atomic Energy Control Board (AECB), in keeping with the federal government's policy on the peaceful uses of uranium as announced in 1965. The 1965 policy was restricted to the area of safeguards. A policy announced in 1969 defined the national interest in terms of future requirements, reserves, ownership, and export considerations (Appendix C).

Control of export is precisely defined in terms of the implications of an export contract in relation to nuclear safeguards, the terms of the contracting parties, reserves, rate of exploitation, domestic requirements, domestic processing facilities, and the selling and pricing policy. Contracts for more than ten years are not approved unless provision is made for renegotiation of price. Canada adheres strictly to the terms of the international Non-Proliferation Treaty for the peaceful uses of uranium.

On March 2, 1970, the Prime Minister made a statement regarding policy on foreign ownership of the Canadian uranium industry. This was expanded by the Minister of Energy, Mines and Resources on March 19 and May 5 of that year (Appendix C). The main points of the policy as then announced were that existing producers would be permitted to maintain the foreign ownership position on March 2, 1970; but any transfers of foreign ownership would have to be to Canadians until foreign ownership was reduced to 33 per cent. Below 33 per cent, ownership could be transferred to other non-residents, but not in amounts that would give equity greater than 10 per cent ownership to any one non-resident. The March, 1970 policy was instituted at the time that the Canadian Government intervened to prevent the sale of Denison Mines to foreign interests, so that the single largest reserve in Canada would not fall under foreign control. Legislation now in preparation will govern the industry under this policy and will be such as to allow the reasonable participation of persons other than Canadians. This participation will provide the prospect of financial returns to make participation attractive to non-Canadian investors while maintaining the high degree of Canadian ownership called for in the 1970 policy statement.

For almost twenty years, the Canadian nuclear research and development program, led by the Crown corporation, Atomic Energy of Canada Limited, has been directed to the objective of economic nuclear electric power. The program is now moving through the advanced development stages into the operations stage in which the provinces are being assisted in establishing their own nuclear reactors and power plants. The Pickering plant in Ontario is now operating with outstanding success, and assistance is being given to Quebec in the establishment of a nuclear power plant in that province. The policy is being directed towards the objective of having a major portion of electric power generation based on nuclear energy by the end of the century. As part of this policy, Atomic Energy of Canada Limited is sponsoring research and development to ensure the establishment of a capability in such activities as thorium refining, plutonium fuel element fabrication and fuel processing to provide for effective use of Canadian ores and thus to ensure the continuing availability of nuclear energy sources as Canada moves into the nuclear energy age.

Federal-Provincial Relationships in the Energy Field

There are many and various provincial government policies that have an important impact on the energy field. Obviously, these policies, and the priorities of the provincial governments which gave rise to them, are significant factors in the development of national energy policies. The federal government anticipates that the provinces, in reviewing and commenting on this report, will have their

own priorities and policies particularly, but not of course exclusively, in mind and that they will bring their interests and concerns to bear on the process of formulating national energy policies. In these circumstances, the existing Canadian energy policies discussed in this report are principally those which are the responsibility of the federal government.

Where there is no overlapping of responsibility, each government can proceed with its own objectives and programs without creating problems for another government. There are, however, relatively few energy policies of the federal or provincial governments that can be formulated and implemented without regard to the impact they could or do have on the objectives and policies of the other governments in Canada. While federal and provincial powers are defined in the Constitution the nature of our federal state is such that many policies are to some degree the result of an amalgam of federal and provincial interests and concerns. While the federal government considers that it is its responsibility to take the lead in the development of national energy policies, it recognizes that, generally speaking, these should evolve from the harmonization of the priorities and policies of the several provinces and of the different regional concerns.

This report is intended, in part, as a major federal contribution to the exchange of information with provincial governments which the federal government would hope could be significantly expanded during the coming months and years. Over the past years federal and provincial departments and agencies have developed close relationships in the energy field, particularly at the technical level. In these discussions, much useful information has been exchanged and problems raised and, in many cases, resolved. The need for effective collaboration is, however, especially acute at a time when overall energy policies are being reviewed and new policies formulated.

That there can be no effective set of national energy policies developed without the participation of the provincial governments is readily apparent. The provinces own 90 per cent of the assets of the electricity generating industry in Canada, they control almost 100 per cent of the oil and gas produced in Canada today, and, when the potential of the oil sands is included, they control a majority of Canada's future petroleum potential. They also hold the rights to almost all of the coal potential which will meet future energy needs. Obviously, policies developed in isolation in Ottawa hold scant hope for success.

There are great challenges here. Canada is faced with the conflcting priorities of the major energy producing and energy consuming provinces. Looked at from the respective provincial perspectives, the differing aspirations cannot be faulted. Alberta quite naturally wants to secure the maximum economic benefit from its non-renewable energy resources. Ontario and the other major consuming provinces do not want to see dramatic or too rapid increases in the cost of energy to their industrial base, especially when some portion of the price increases appears to be prompted by conditions within the United States rather than domestically.

In discussing approaches to and components of national energy policy with provincial governments, the federal government must bring an understanding of both the regional and the overall national consequences of the various courses of action being advocated. To what extent, for example, will energy price in-

creases affect Canada's competitive position in world trade? To what extent will they increase the cost of consumer goods in Canada? What benefits will flow to the producing provinces? To the producing industries? Will the increased revenues to the producing industries leave Canada in the form of dividends or be reinvested in further exploration work? What resource base will become a viable asset as the value of the energy commodities rise?

At a time of recasting national energy policies, it is important to examine the relationship between those federal and provincial policies that were designed to deal with major issues. Federal-provincial relationships in the energy field, for each of the energy sources, are worth examining to indicate those areas where responsibilities are well defined and those where priorities conflict—either between provinces or between the federal government and one or more provinces—and where improved policy coordination appears to be required.

Current concerns and differences of perspective about prices of oil and gas and the allocation of production of domestic and export markets are obviously major considerations in any review of policy. The National Oil Policy of 1961 and the natural gas pricing and market allocation procedures of the past 20 years may, for example, require revision to ensure that policy is appropriate to national needs, not only because of changing domestic circumstances, including the reliance that will have to be placed on frontier resources, but also because of changing circumstances in the United States and in the international oil industry.

Federal coal policies must take account of provincial policies and programs concerned with conservation of resources and safety of mining operations, and with the terms and conditions under which mining rights are allocated, including royalty provisions. Traditionally, most financial support of marginal coal mining operations has come from federal sources. As the industry changes from its former heavily subsidized status to viable operations, provincial governments may play a larger role. The federal role could then be concentrated on national resource appraisal programs and encouragement of the best use of coal, whether in the domestic or the export market, with future energy needs of the country in mind.

Jurisdictional issues associated with uranium are complex because of the strategic nature of uranium and because of a number of uranium industry activities that the federal government is involved in, along with its international obligations under the Non-Proliferation Treaty. National uranium policy is expressed, in part, in terms of the extensive controls of the Atomic Energy Control Act. However, because of the increasing importance of uranium as an energy mineral, provincial governments find some of the federal controls a constraint in activities associated with exploration, mining and processing. At the same time, provincial governments recognize the value to the industry and uranium mining localities of the federal government's uranium stockpile policy.

The uranium and nuclear energy industries have been greatly aided by the federal government's policy on research and development as carried out by Atomic Energy of Canada Limited during the past 20 years. This policy is making it possible for provincial government utilities to establish nuclear energy plants as part of their electric power systems. National policies for uranium and nuclear energy have been essential because of the large costs and skilled manpower requirements needed to develop a new energy source into a state of practical application. As

nuclear energy is taken into greater use, the federal-provincial policy relationship will change in accordance with the increasing responsibilities of the provinces. As with other sources, the federal role will concentrate on resource appraisals and the allocation of resources to markets that will serve the national interest, and the encouragement of research associated with these activities.

Electric power plants and transmission lines have always been considered as local works and undertakings, coming within the jurisdiction of the provinces. The federal government has responsibility for international power lines and for exports of electricity. The National Power Policy of 1963 (*see* Appendix C) placed particular emphasis on the following objectives: encouragement of technological improvements and of economic development; provision of power to Canadians at the lowest possible costs; and a flexible export policy to enable the development of certain large hydro projects which might not be viable unless a significant portion of their output could be exported for a predetermined period. The federal role is therefore evolving from one of, primarily, export control, to one where the provincial utilities are encouraged to expand and improve the efficiency of their operations through system interconnections. The federal government also supports research and development on power systems and, as noted, cooperates with the provinces in the establishment of nuclear power plants.

Provincial and federal policies concerned with electric power are possibly more complementary than is the case with other energy sources. A consensus on national objectives and areas of jurisdiction for electric power has developed to a much greater degree than for other energy sources. The process of achieving a consensus will continue.

The federal government, moreover, seeks to develop a national consensus about the direction energy policies should take. It hopes that such a consensus will emerge, in part, from the consultations it intends to carry out with the governments of the provinces. The federal government has already assured provincial governments that it intends to obtain their views about the impact upon the provinces of possible federal energy policies before any final decisions with respect to them are reached by the Government of Canada. It is envisaged, however, that the participation of provincial governments in the formulation of national energy policies would involve more than was implied in that assurance.

A National Conference on Energy might be an appropriate forum to initiate the process of building a consensus, though bilateral consultations with provincial governments will play a most important part. Given the varied and sometimes divergent factors that must be taken account of, the process of attempting to reach a consensus cannot be expected to be rapid or without difficulty. The importance of the issues involved calls for a determined and sustained effort by governments to establish a spirit conducive to cooperation and flexibility.

SECTION II

CANADA'S ENERGY—OUR NEEDS AND OUR RESOURCES

Chapter 1

INTRODUCTION

Today, many Canadians are concerned about the magnitude of Canada's future energy requirements and our ability to supply these requirements over the long run. This concern is often linked with our continuing exports of oil and natural gas to the United States and to the powerful demand factors in that country which reflect its current energy problems. Apart from the physical movement of energy resources out of Canada, there is concern about the price at which we export energy products. On one hand we wish to optimize our price to the United States and receive fair value for our exports, and on the other we are fearful that fuel prices in Canada will increase, reflecting high opportunity prices in export markets. In particular, it is argued that increased energy costs to Canadian industry will erode our competitive strength and that the maintenance of lower costs would enhance our comparative advantage.

The following chapters provide a long-term view of Canada's energy demand and supply position, i.e. over the next 27 years to the year 2000 with an illustrative example to the year 2050. Variations in demand are set out to illustrate the possible ranges in future energy requirements. Potential energy supply is related to future cost and price levels set within an international price context. It is important to emphasize that the prime thrust of this analysis is towards the long term. Short-term solutions to current problems should be compatible with national policies set within long run perspectives.

Forecasting future supply/demand relationships is a difficult and hazardous task. Generally speaking, past forecasts of energy demand have been too low and, with some notable exceptions, estimates of available supply have been too pessimistic.

Twenty-seven years ago, in 1946, the Chairman of the Royal Commission on Coal wrote that "despite the importance of alternative sources of energy, coal is, and will probably continue to be, the most important source of energy for railway locomotives and industrial and domestic heating". In November of 1946 an oil well was spudded near the town of Leduc, Alberta, which proved to be Western Canada's first oil discovery in 11 years and the start of a new era. In 1946 coal supplied close to 60 per cent of Canada's energy requirements compared to 11 per cent today.

Several other viewpoints expressed in the report of the Royal Commission on Coal are interesting in today's perspective. In 1946 Canada produced 17 per cent of its petroleum requirements. This production came primarily from the Turner

Valley Field in Alberta where output was declining. Prairie oil requirements were being satisfied, to an increasing degree, by imports of oil from the mid-continent fields in the United States. At the same time, British Columbia and Ontario relied in part on oil imports from the United States while Quebec and the Maritime Provinces imported most of their supplies from Latin America. Given this situation the Commission's report stated that "Concern has frequently been expressed as to the adequacy of United States sources to meet the growing demand. If in fact a shortage should develop, the price which Canadian importers would have to pay for their crude requirements would rise considerably, . . .".

Turning to natural gas, the report speculated on the feasibility of a natural gas line from Alberta to markets in Saskatchewan and Manitoba and the adequacy of known reserves to support such a line. The report stated "Even should reserves in Alberta be adequate and the economics of the pipeline . . . be sound, no company would undertake any large pipeline construction without an assurance that the government of Alberta would allow the export of gas over a long period of years. It is by no means certain that such assurances would be forthcoming. . . . it is possible that the government would discourage the export of gas in the hope of attracting chemical industries to the province . . .".

Although the Commission did not foresee the transformation of the Canadian energy economy from coal to oil and natural gas, their concerns over future requirements and adequacy of supply and the price of energy commodities are still the major concerns facing Canada today. In addition to these, however, several other factors and attitudes have complicated the supply/demand equation. Environmental problems will substantially affect energy developments. Concerns related to absolute shortages of energy resources in the future have encouraged a strong movement towards conservation. Recent international events, particularly related to international oil movements and the concentration of oil production in the Middle East, have tended to change attitudes towards security of supply. Over the past decades many nations have moved from self-sufficiency in energy towards a large import position. International trade in petroleum and other energy commodities has grown very rapidly, and international price movements will be an important factor affecting future supply/demand relationships in Canada.

This Section will explore these and other related matters.

Chapter 2

PRICE DEVELOPMENT OF FUELS

Generally speaking, over the last two decades, energy prices have been declining. However, since 1971, there has been a fundamental shift to much higher crude prices internationally. This basic change was primarily due to tax increases levied by major oil exporting countries (OPEC).

Crude oil prices are expected to increase substantially in the future. In 1990 crude oil prices will be more than double today's prices (in constant 1972 dollars). In the long run, Canadian crude prices will reflect international crude price developments.

Natural gas in Canada is currently under-valued in most market areas in relation to other fuels. More flexibility in gas pricing is necessary if natural gas market values are to keep pace with increasing prices of competitive fuels. The cost of gas to distribution companies in 1990 could be 2 or 3 times current levels.

Electricity costs, now experiencing rapid increases, will flatten off by 1980 in terms of real cost to the consumer and should not increase significantly thereafter because of advances in nuclear technology and low nuclear fuel costs.

It seems possible that the demand for the price of fuels may in future be influenced by competition for environmentally "clean fuels". Environmental assessments may be needed to aid in determining the ultimate "best use" of clean fuels.

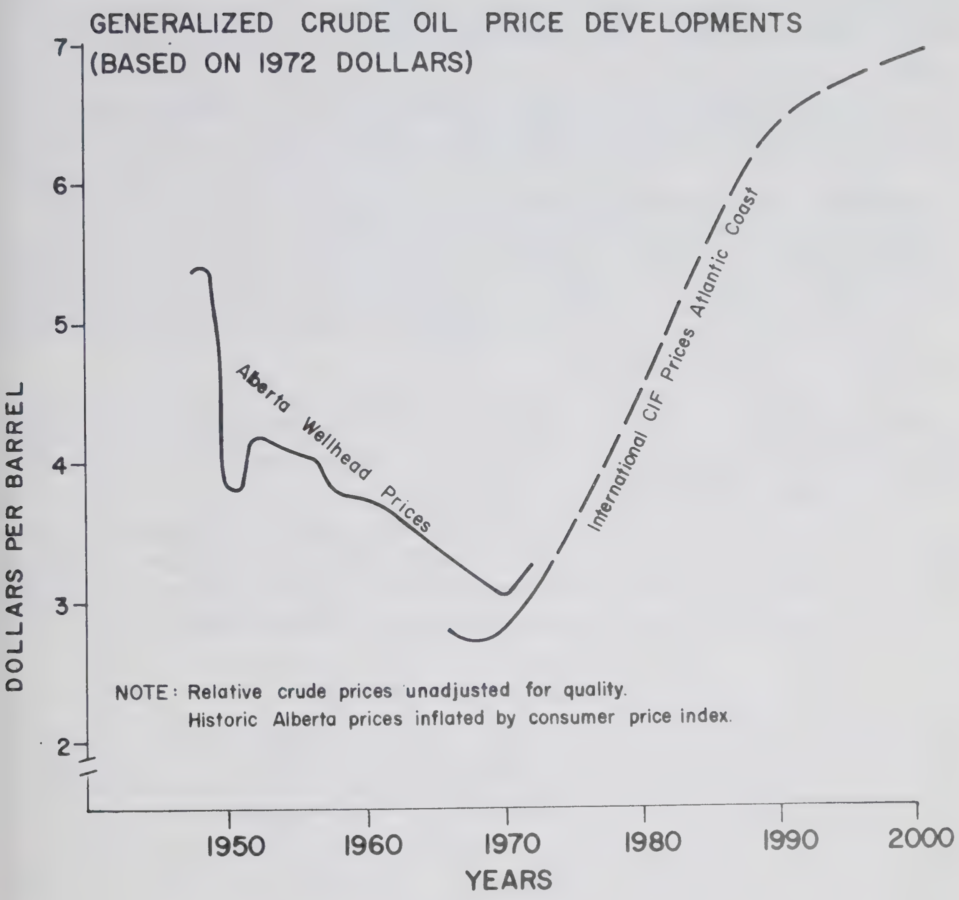
PETROLEUM

As a result of the National Oil Policy announced in 1961, Canada was divided into two areas as far as crude oil supply is concerned. All of Canada west of the Ottawa Valley line was reserved for domestically-produced crude oil. East of the Ottawa Valley line, imports of foreign crude products were allowed to continue. With the exception of heavy fuel oil which was not under import control, petroleum product prices west of the line reflected crude price movements in Western Canada while product prices in Eastern Canada were determined by international price development.

During the 1960's, crude prices in Western Canada and the United States were considerably higher than imported crude prices. The differential was maintained by the National Oil Policy in Canada, and by the U.S. Oil Import Regulation.

International Crude Pricing

Prior to 1958-1959 the price of crude oil moving in international trade remained fairly stable. Crude oil coming from the major producing regions of the Middle



GENERALIZED CRUDE OIL PRICE DEVELOPMENTS
(BASED ON 1972 DOLLARS)
DOLLARS PER BARREL
7
6
5
4
3
2
Alberta Wellhead Prices
International CIF Prices Atlantic Coast
NOTE: Relative crude prices unadjusted for quality.
Historic Alberta prices inflated by consumer price index.
1950
1960
1970
1980
1990
2000
YEARS

Chart 1

East and Venezuela was, for the most part, controlled by major international oil companies. In the late 1950's competition, due to the entry of independent producers and a general surplus condition, created downward pressure on international crude prices. Tax payments to host governments were also reduced due to reductions in posted prices[1]. As a result of decreasing oil tax revenues the Organization of Petroleum Exporting Countries was formed, in 1960, in an effort to restore posted prices to 1958 levels. Although OPEC achieved little success in the 1960's in increasing their tax take they did manage to stop any further decreases in posted prices. Generally speaking, real crude prices continued to decline throughout the decade.

In early 1971 agreements between the OPEC countries and producers—the Tehran and Tripoli Agreements—significantly increased the tax on crude oil production. These agreements were followed by the Geneva Agreement which protected the producing countries against currency devaluation. The net result was to substantially increase the price of crude oil moving in international trade. These agreements are to be renegotiated in 1975 and there is every expectation that further tax increases will result. In addition to increased fiscal terms, agreements have been made providing for producing governments to acquire increasing percentage ownership in producing companies.

Crude prices are expected to escalate rapidly from today to 1985, and from 1985 to 2000 the price will increase at a more moderate rate due to the competition from synthetic or unconventional sources such as oil shales, oil sands, and coal liquefaction. (Chart 1).

The forecast shown on Chart 1 is for import prices for foreign crude oil laid down on the east coast of North America. The quality of the crude that has been assumed for this price estimate is light Persian Gulf crude with relatively high sulphur content compared to most North American crude oils.

Domestic Crude Prices

Generally speaking, Canadian crude prices reflect United States crude price developments. Today Canadian crude delivered to Chicago is more or less competitive with similar quality United States crude delivered to the same point. As a result of the proximity and the established trade pattern between Canada and the United States, it is likely that Canadian crude prices will continue to reflect crude price movements in the United States unless some government mechanism is developed to insulate Canadian prices from U.S. price influences.

The differential between United States domestic crude prices and imported crude prices in the 1960's ranged between $1.00 to $1.50 depending upon tanker freight rates at any particular time. With the rapid price increase of foreign crude and currently high tanker rates, the differential between foreign crude and domestic crude has decreased substantially. As a result of the new United States oil import program domestic crude prices both in Canada and the United States can be

[1] Up until the mid to late 1950's, the term "posted price" could be defined as the price at which oil companies "listed" their crude for sale to non-affiliated third parties in "arms-length" transactions. Subsequently, as price cutting occurred and the relationship between the posted price and real crude trading prices disappeared, the term "posted price" has come to mean the price upon which host country taxes and royalties are based; in effect, a tax reference price.

expected to assume a competitive posture with foreign crudes, subject to the payment of a licence fee for crude oil imports into the United States. Appropriate adjustments for crude quality and transportation differentials must also be taken into account.

It has been assumed for the purposes of the supply/demand analysis in this Section that foreign crude prices will set the tone for North American crude prices, and that for the first time in many years North American crude and product prices will reflect international price developments (subject to the U.S. licence fee system). This is an important assumption because the market price available will dictate to a very considerable degree the amounts of new energy sources in Canada that can be developed. As later chapters will show, if Canadian prices are held down the resources available are reduced and, at the same time, a greater domestic demand than projected may develop.

International price movements for crude oil will be reflected in petroleum product prices and affect the competitive selling prices of other energy sources. Chart 1 shows the historic development of Alberta prices over the last 20 years. Actual values have been adjusted for inflation using the consumer price index.

Natural Gas

Currently natural gas prices in Canada vary widely, and are largely dependent upon the distance of the market centre from Alberta, the major producing area. Several factors have determined natural gas prices in Western Canada, not the least of which is the existing level of controlled natural gas prices in the United States. Currently, gas is undervalued in most market territories when compared with competitive petroleum products such as light and heavy fuel oil. Current gas price negotiations in Alberta between pipeline companies and producers centre around this undervaluation. When frontier gas starts to penetrate markets in Canada and the United States the costs of this new gas will be substantially higher than existing gas prices in Canada. It is clear that frontier gas would not be developed if it had to be sold at current "city gate"[1] prices. Transportation charges alone would substantially exceed the current city gate prices in all market areas.

In order to determine the development potential of frontier gas, both on the east coast and in the Arctic, it was necessary to forecast future average city gate prices in prospective market areas (e.g. the Great Lakes area). Chart 2 shows the historic development of city gate prices during the last decade and illustrates a forecast of average city gate prices to the year 2000. The price range is based on the fact that gas does have form value or premium value relative to other fuels and may be able to realize some or all of this premium value in the marketplace. As city gate prices increase the mix of consumers is likely to change as large industrial customers may tend to shift to other fuels. The gas price forecast is tied generally to crude oil price increases with the general assumption that gas price determination will be flexible enough to move upwards reflecting the price of competitive fuels.

[1] The city gate price of natural gas is normally considered to be the price paid by the city distributor (retailer) to the transmission company or supplier (wholesaler) at the junction of their facilities prior to the addition of the local utility's distribution charges.

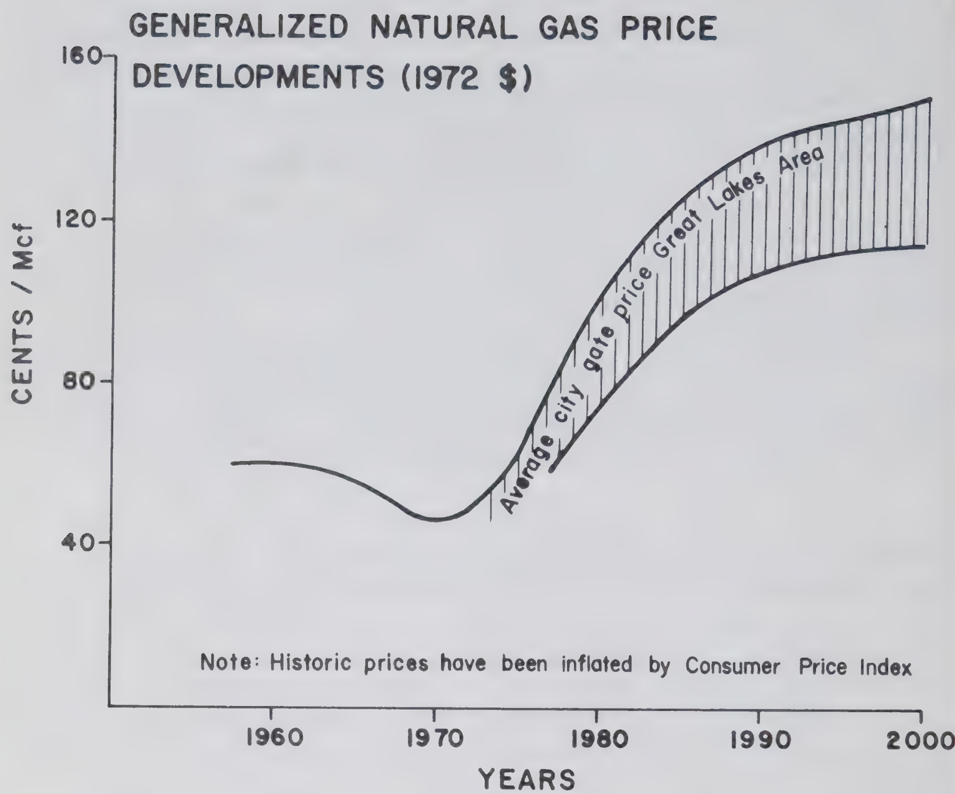


Chart 2

Again, it is a hazardous exercise to forecast future gas prices over the next three decades. Institutional factors, distribution and transmission economics, and environmental concerns, make this forecast subject to considerable uncertainty.

One important distinction must be made between the possible sales price of gas in Canada compared to export markets in the United States. There is the possibility that Canadian gas can be sold in the United States at higher prices than in Canada because United States distributors have the ability to "roll in" high cost gas with low cost "vintage" gas which is under wellhead price control by the Federal Power Commission. The policy implications of this situation are discussed later in this Section.

The average city gate prices illustrated in Chart 2 were used in the supply forecast to estimate the rate and extent of frontier gas development.

Coal

The two major markets for coal in Canada are the iron and steel industry and thermal power generation. It is highly unlikely that thermal coal prices in general will differ significantly from competitive oil or gas prices in the future. Costs associated with the utilization of coal are substantially higher than for oil or natural gas and these utilization costs will be reflected in the prices set for coal at the mine. As the crude oil price moves into the $5.00 to $7.00 a barrel range (constant 1972 dollars) coal liquifaction and gasification will become a real alternative to conventional oil and gas supplies.

Metallurgical coal prices in Canada will be influenced by international market forces and the cost of coal to the Canadian iron and steel industry will be in the order of $22.00 to $25.00 a ton by 1980 (constant 1972 dollars). The price ceiling on the European market will be established by the cost of indigenous supplies including social costs. On the other hand, the international competitive market price will be governed by the cost of supplies from countries such as the United States, Australia and Canada. Cost stability in these countries will be subject to world demand pressure and the need for continuing environmental improvements affecting both surface and underground production. Should formed coke processes be developed based on strippable low rank coals by mid-1980, increased use of these lower rank coals for formed coke and char should stabilize prices.

A more detailed discussion of the availability of coal resources at various cost levels is set forth in the resources chapter of this Section.

Uranium

The potential uranium resources available in Canada are extremely large. Current prices for U_3O_8 in Canada and throughout the world are about $6.00 per pound. Depending largely on the extent of international exploration and discovery, the price of uranium in Canada could rise by the year 2000 to the point where it would be economic to recover some of those resources now delineated within the category of $10.00 to $15.00 per pound. In the period 2000-2050 the price probably will not exceed $20.00 per pound in 1972 dollars, and at this price level enormous volumes of U_3O_8 become available from very low grade sources throughout the world.

As uranium costs account for only a small part of total nuclear power cost, about 3 per cent at present, the future price of electricity will not be appreciably affected by uranium price increases over the forecast period. The impact of increasing prices for U_3O_8 is discussed in the resources chapter.

Chapter 3

CANADA'S ENERGY REQUIREMENTS

Assuming no major changes in government policies or Canadian attitudes towards energy use or conservation, Canada's energy requirement in the year 2000 could be about four times that of 1970. Primary electricity—nuclear and hydro power—would account for about 30 per cent of the total. Depending upon Arctic and east coast discoveries, natural gas could increase its contribution to overall requirements substantially.

Increasing prices for energy commodities will tend to moderate demand growth rates in the long run. Energy consumption per capita over the period to 2000 would increase at an average of about 3 per cent per year as compared to 4 per cent during the last decade.

There is considerable uncertainty about future energy consumption patterns. Changes in life styles of Canadians, changes in the economic structure of the nation, and government policies relating to the environment or conservation can have an important impact on energy demand. The consumption forecast could be 15 per cent higher or 25 per cent lower than the standard forecast for the year 2000 depending on these factors. The range could be even wider if economic growth or population levels are far different from standard projections.

Canada's energy requirements are determined, in part, by the kind of society Canadians want to build in the future. It is unrealistic to forecast future energy requirements based on historic trends alone. Canadians can influence the magnitude and structure of energy demand. Government policy decisions influencing the kind of economic activity in the country and changes in the utilization of energy due to environmental or conservation policies will affect total energy requirements. Even larger effects will result from the pace of economic development, i.e., the growth rate in GNP, and the growth in population over the next three decades. In order to illustrate possible variations in energy demand over the forecast period to the year 2000, a base case or standard forecast has been prepared along with estimates of how this standard forecast could change as a result of a series of different assumptions affecting the nature and pace of economic activity, population growth and other concerns such as environmental protection and conservation policies. The standard forecast is not presented as an objective, but rather as an indication of the possible results of a "business as usual" approach and as a reference point against which to measure the effects of changes in policies and attitudes.

The Standard Forecast

The standard forecast is based on a series of assumptions which represent a neutral or middle-of-the-road position. The first and most important assumption is that there will be no great change in attitudes and government policies. Secondly, it is assumed that future energy prices in Canada will be determined in the long run by international price considerations. The forecast assumes a population of between 34 and 35 million people by the year 2000, and that an ever-increasing share of the population will be employed in service industries. Further, it assumes that advances will be made in environmental protection through such measures as automobile emission controls, and that the rising cost of energy and environmental and conservation forces will result in modest increases in efficiency of energy utilization. The effect of environmental and conservation measures on the standard forecast are described in Appendix A which provides greater detail on the forecast of energy requirements.

The standard forecast is essentially a sector forecast. Separate forecasts were prepared for each end-use sector; transportation, residential, commercial and industrial. The end-use requirements were then aggregated to arrive at a total secondary energy demand forecast. This forecast is set out in Table 1. Charts 1 and 2 illustrate secondary energy demand by product and by end-use sector.

Secondary energy consumption includes petroleum products, natural gas, coal and electricity. Conversion losses in the energy industries such as electric power plants are not included in the estimates for secondary demand. In order to arrive at primary energy consumption the conversion losses incurred in supplying secondary energy demand must be calculated. Addition of these conversion losses and estimates of waste leads to the forecast of primary energy requirements in Canada. Table 2 sets out the primary energy forecast.

Due to the uncertainty of the relative prices of crude oil and natural gas in the future and uncertainties relating to the availability of natural gas, a range is used for both oil and gas demand. Assuming large scale availability of natural gas for eastern Canadian markets the most likely primary demand for gas is between 7 and 8 x 10^{15} Btu in the year 2000, and for oil between 10 and 11 x 10^{15} Btu. Chart 3 illustrates the expected growth in primary energy demand in Canada over

Table 1

STANDARD FORECAST OF CANADA'S SECONDARY ENERGY CONSUMPTION
(10^{15} Btu)

	1970	%	1980	1990	2000	%
Petroleum products	2.9	58	4.6–5.1	6.0–9.4	8.2–13.5	79
Natural Gas	1.1	22	2.5–2.0	5.4–2.0	7.7–2.4	
Coal[1]	0.3	6	0.3	0.3	0.4	2
Electricity	0.7	14	1.4	2.4	3.9	19
Total	5.0	100	8.8	14.2	20.2	100

Figures may not add up to totals due to rounding.
[1]Includes petroleum coke.

TABLE 2

STANDARD FORECAST OF CANADA'S PRIMARY ENERGY CONSUMPTION
(10^{15} Btu)

	1970	%	1980	1990	2000	%
Petroleum	3.1	48	4.8–5.4	6.7–10.2	9.4–14.6	63
Natural Gas	1.2	18	3.1–2.5	6.0–2.5	8.2–3.0	
Coal	0.7	11	1.1	1.6	1.9	7
Hydro Electricity*	1.5	23	2.3	3.1	3.4	12
Nuclear and other	—	—	0.5	2.0	5.1	18
Total	6.5	100	11.9	19.4	28.0	100

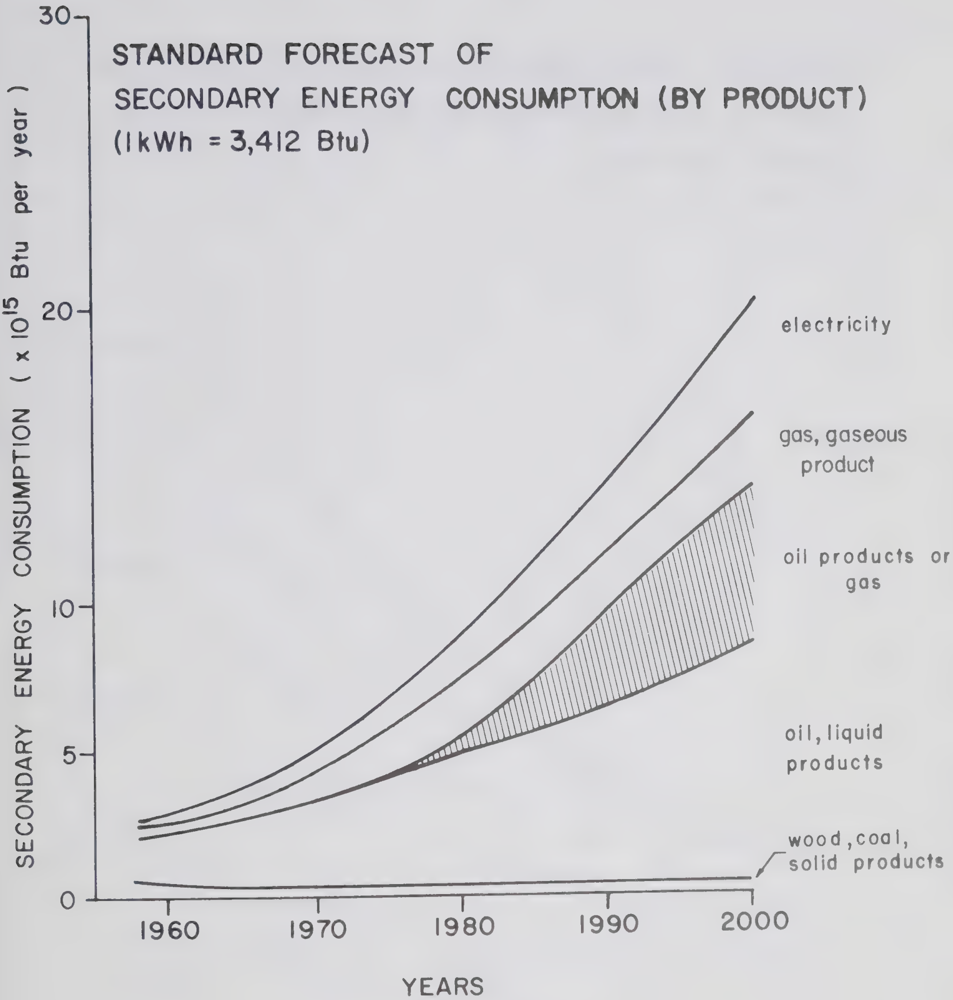
*Hydro electricity at 10,000 Btu per kWh.
Figures may not add up to totals due to rounding.

(Natural Units)

	1970	1980	1990	2000
Petroleum (MM. bbls/day)	1.5	2.3–2.5	3.2–4.8	4.4–6.9
Natural Gas (billions of Mcf)	1.2	3.1–2.5	6.0–2.5	8.2–3.0
Coal (millions of tons)	26	49	84	100
Hydro Elect. (billions of kWh)	157	235	310	344
Nuclear (billions of kWh)	1	45	180	502

the forecast period. Consumption in the year 2000 is about four times the consumption in 1970. The overall growth rate in energy demand tends to decline over the forecast period. The single most important change in primary energy consumption will be the rapid development of nuclear power. Nuclear power will contribute about 18 per cent of total energy in the year 2000 compared with a negligible percentage today. Total primary electricity (nuclear and hydro) will comprise close to 30 per cent of total energy needs by the end of the century.

In the process of estimating future energy requirements in each sector the effect of rising energy prices was considered. Energy prices, as pointed out in a previous chapter, are expected to increase substantially over the forecast period. There is considerable uncertainty about the price elasticity of energy as a whole. In the short run it would seem that energy demand is not very responsive (inelastic) to price changes. In the longer run, however, demand may be moderated significantly by higher prices. The standard forecast does incorporate some moderation of demand due to rising prices. The demand growth rate for gasoline is lower than it might be under conditions of price stability. As home heating fuel prices increase, a trend towards the use of more insulation and an increase in electric heating is forecast as electric power rates are not expected to increase as rapidly as fossil fuel prices. User habits may also change both in the residential and the transport sectors which could result in lower demand. Industry will become more sensitive to energy costs and efforts will be made to improve efficiency in energy utilization. It is expected that these factors will influence demand by natural forces, without government intervention.



STANDARD FORECAST OF
SECONDARY ENERGY CONSUMPTION (BY PRODUCT)
(1kWh = 3,412 Btu)
SECONDARY ENERGY CONSUMPTION (x 10^15 Btu per year)
30
20
10
5
0
1960
1970
1980
1990
2000
YEARS
electricity
gas, gaseous product
oil products or gas
oil, liquid products
wood, coal, solid products

Chart 1

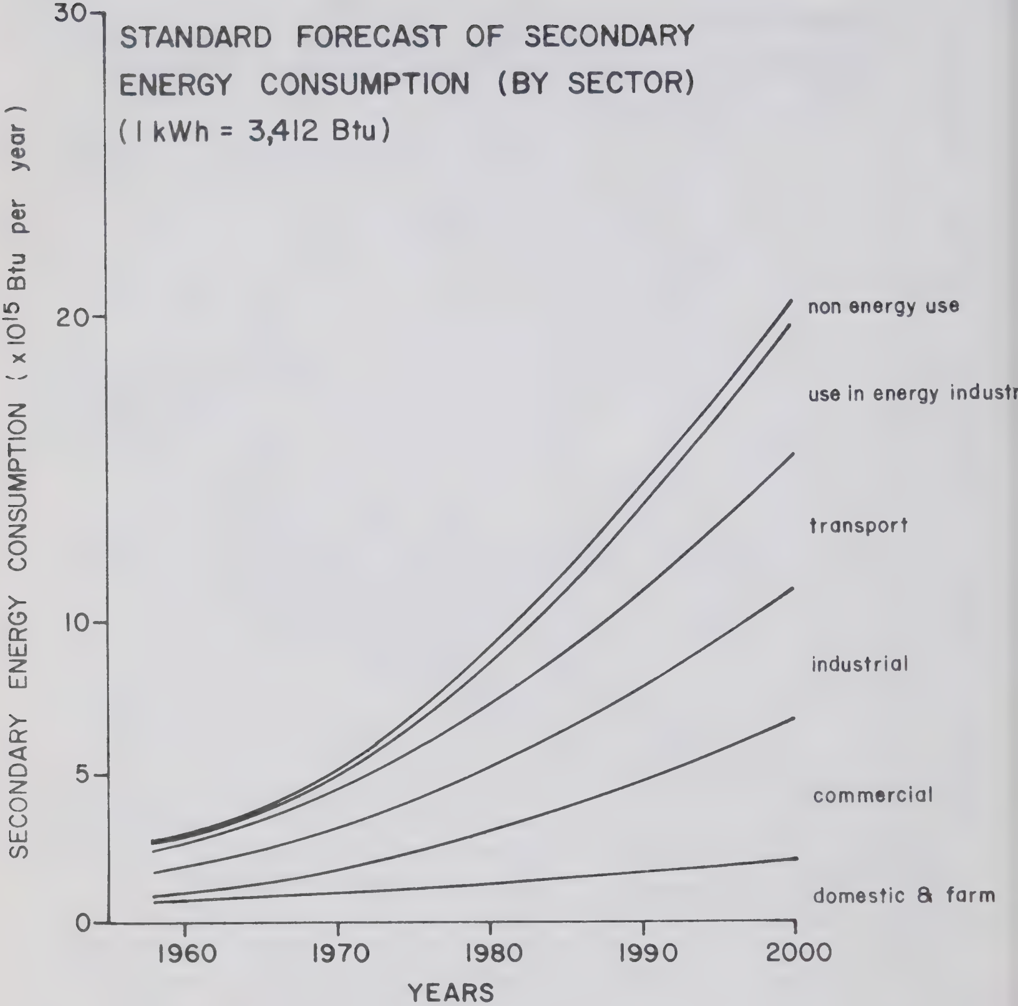

STANDARD FORECAST OF SECONDARY ENERGY CONSUMPTION (BY SECTOR)
(1 kWh = 3,412 Btu)
SECONDARY ENERGY CONSUMPTION (x 10^15 Btu per year)
30
20
10
5
0
1960
1970
1980
1990
2000
YEARS
non energy use
use in energy industr
transport
industrial
commercial
domestic & farm

Chart 2

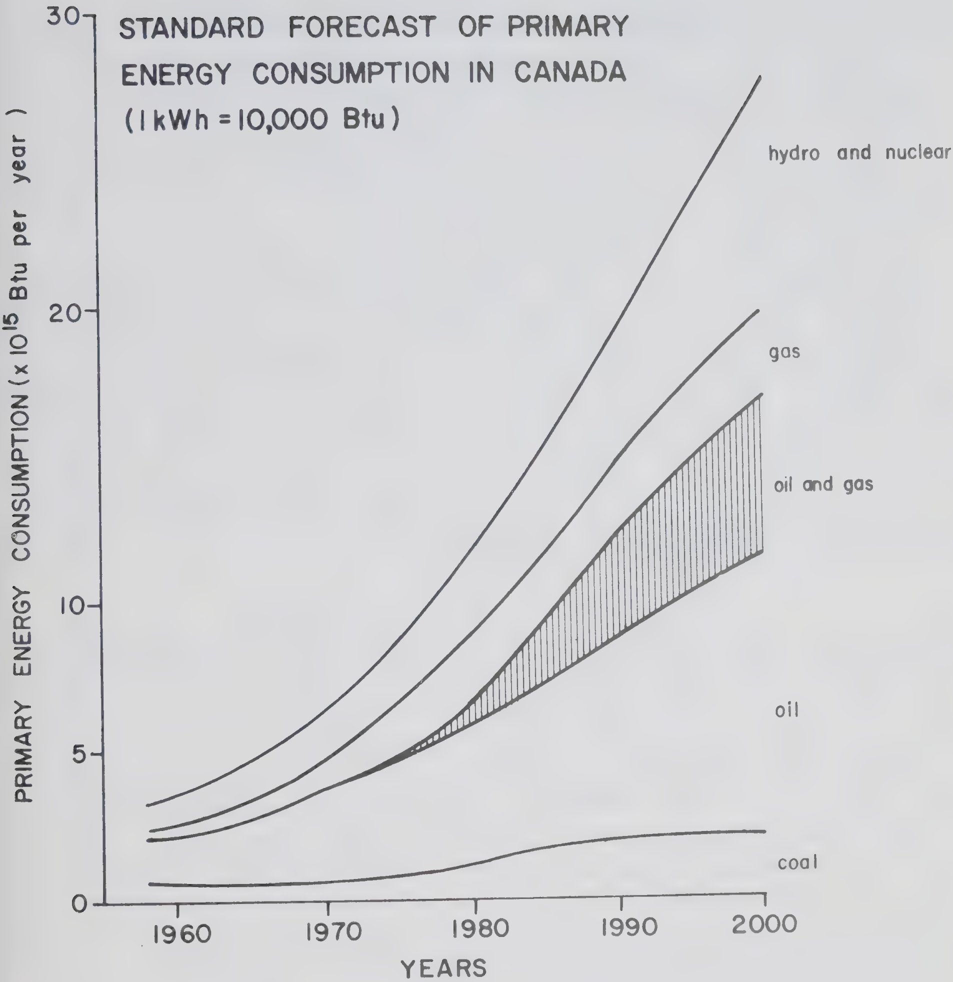

STANDARD FORECAST OF PRIMARY
ENERGY CONSUMPTION IN CANADA
(1 kWh = 10,000 Btu)
PRIMARY ENERGY CONSUMPTION (x 10^15 Btu per year)
30
20
10
5
0
1960
1970
1980
1990
2000
YEARS
hydro and nuclear
gas
oil and gas
oil
coal

Chart 3

The Growth of Population and the Economy

The growth of the population and the economy could have a considerable influence on increases in energy consumption. Chart 4 illustrates how wide these variations could be. The standard forecast assumes a population between 34-35 million people in the year 2000. However, under different assumptions, population could be as high as 38 million or as low as 29 million.

A study of secondary energy consumption per capita suggests that consumption could grow from 250 million Btu per person in 1970 to 580 million Btu in the year 2000. The growth rate in the last decade has been slightly less than 4 per cent per year. The standard forecast indicates that this rate of growth could continue for the next two decades, but might decline towards the year 2000. The standard forecast suggests an average annual increase over the forecast period of slightly less than 3 per cent.

The relationship between GNP and energy consumption can change quite substantially in the future according to changes in life styles, changes in the nature of industrial activity or changes in government policy.

As can be seen on the graph in Chart 5, the ratio of energy consumption to GNP declined until 1960 and has remained approximately constant for the last fifteen years. The decline can be largely explained by the increasing efficiency of energy conversion and use. Advances of the same magnitude are not expected in the future. It is judged, in fact, that a slight increase in this ratio is a reasonable expectation. If GNP per capita varied by $\pm$ 25 per cent in the year 2000, total energy consumption could range from 12 to 27 x 10^{15} Btu as shown in Chart 4. It is very unlikely that these extreme values will occur, but the figures indicate the close relationship between the development of the economy and Canada's population and total Canadian energy consumption.

Variations on Energy Demand

As previously noted, the Standard Forecast reflects the probable results of a "business as usual" approach to energy. No major shifts in government policy were assumed, price levels were allowed to follow international trends, and no serious restraints on energy use resulted from environmental or energy conservation movements. All of these factors can, and will, affect the demand for energy in Canada over the next twenty-five years. Government policies will change, Canadian energy prices may well be insulated to some extent from world trends and environmental and conservation concerns will affect the mix and total demand for energy. These individual factors which affect energy use could change in ways by which they would all work to move energy demands in one direction, but more likely they will offset one another to some degree. This section of the analysis of requirements attempts to determine the maximum total impact which these factors might have on the Standard Forecast. Further detail is given in Appendix A.

As far as government policies are concerned, decisions relating to environment, conservation of resources, transportation, urban and regional development, industrial development, and other policies could affect Canadian energy requirements. In view of the fact that most policy changes will have their full impact in the very long term, the effect of the various changes with reference to the year 2000 is discussed.

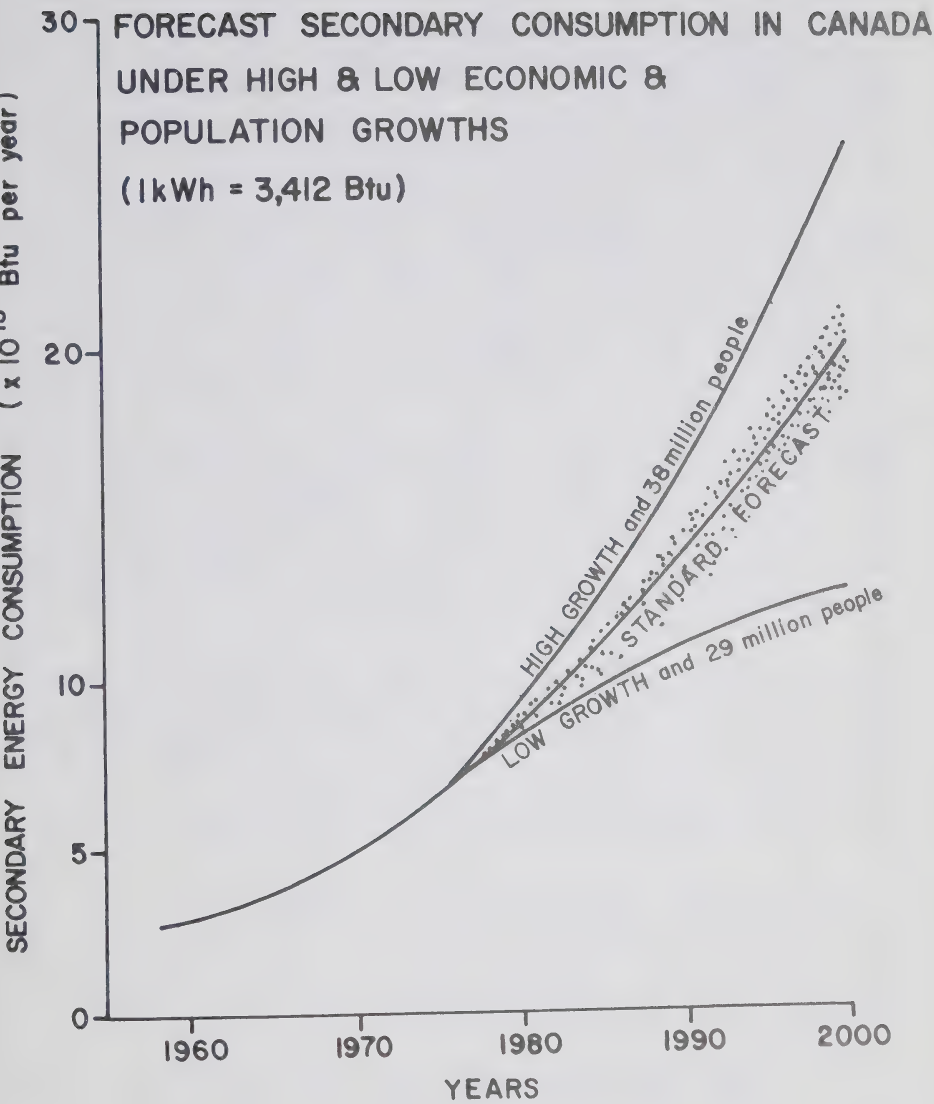

FORECAST SECONDARY CONSUMPTION IN CANADA UNDER HIGH & LOW ECONOMIC & POPULATION GROWTHS
(1kWh = 3,412 Btu)
SECONDARY ENERGY CONSUMPTION (x 10^15 Btu per year)
HIGH GROWTH and 38 million people
STANDARD FORECAST
LOW GROWTH and 29 million people
0
5
10
20
30
1960
1970
1980
1990
2000
YEARS

Chart 4

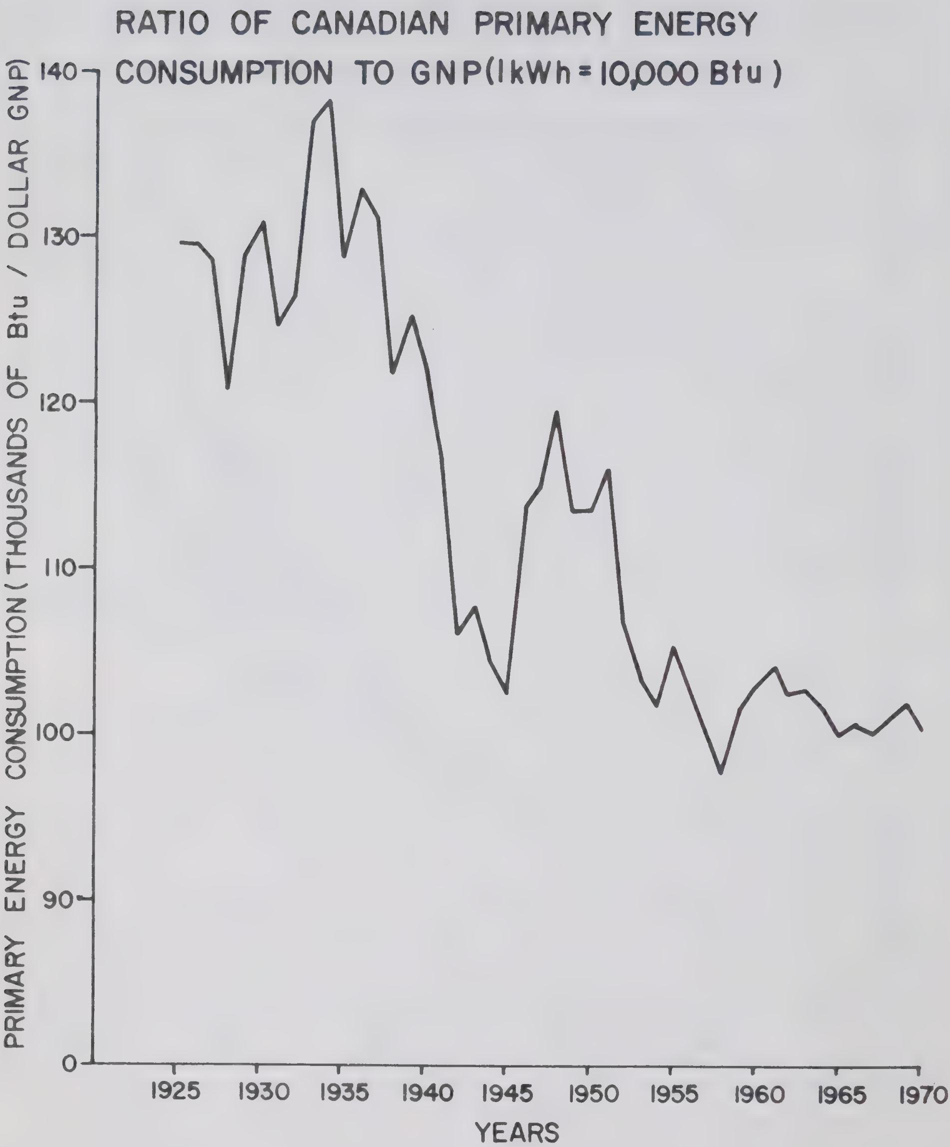

RATIO OF CANADIAN PRIMARY ENERGY
CONSUMPTION TO GNP(1kWh = 10,000 Btu)
PRIMARY ENERGY CONSUMPTION (THOUSANDS OF Btu / DOLLAR GNP)
140
130
120
110
100
90
0
1925
1930
1935
1940
1945
1950
1955
1960
1965
1970
YEARS

Chart 5

Residential fuel demand can be influenced directly by government policies that could tend to change the fraction of the population that lives in apartments. Residential fuel demand could be about 5 per cent higher or lower depending on practical estimates of the mix between single dwelling units and apartments in the year 2000.

Fuel consumption would also be affected by the amount of insulation that is required in the construction of new homes. It is often argued that houses in this Canadian climate should be better insulated and consequently save energy and fuel costs. In view of the expected future prices for fuel it could well be profitable to opt for more insulation in new home construction thus trading off higher annual fuel costs for increased initial capital costs. The standard forecast assumes a shift toward electrically heated homes with higher insulation standards. No appreciable change in insulation standards was assumed for new homes using fossil fuels.

In new dwellings "electrical standard" insulation could reduce energy consumption by upwards of 30 per cent per dwelling compared to current insulation standards. If, in all new dwellings, "electrical standards" for insulation were adopted, total fuel consumption in the domestic sector in the year 2000 could be reduced by about 7 per cent. Other measures which would also be partly applicable to old homes and apartments could reduce fuel consumption by 10 per cent to 13 per cent.

Energy consumption in the industrial sector could vary considerably according to policies of the government to stimulate or reduce industrial activity in Canada. Changes in the expected growth patterns of four important energy consuming industries: the pulp and paper industry, the chemical industry, the iron and steel industry, and the metal smelting and refining industry, could create an energy demand that is 20 per cent higher or lower than the standard forecast of the industrial sector.

Probably the most influential role that can be played by the government in the area of future energy consumption is in the transportation sector. Stronger environmental regulations could increase gasoline consumption of cars by 10 per cent or 20 per cent. On the other hand, a whole complex of measures such as more efficient air transport, smaller cars, more mass transport, etc., could decrease total energy consumption in the transport sector in the year 2000 by over 20 per cent.

The most important segment of the transport market is road transport, accounting for 65 per cent of the total energy consumption in this market. In the standard forecast gasoline demand per car was assumed to remain fairly constant in the future. There will be a trend towards smaller cars using less gasoline largely because of higher gasoline prices. On the other hand, longer driving distances in larger and more crowded urban concentrations and more stringent environmental controls will increase gasoline consumption. These trends tend to offset one another. However, government influence to promote fewer and smaller cars could reduce gasoline consumption substantially, by as much as 30 per cent or 40 per cent in the year 2000. Such actions must occur simultaneously with the development of mass transportation systems. The fuel savings resulting from reduced automobile consumption would only be slightly offset by increased use by the mass transport systems.

It is rather hard to evaluate the impact of changing lifestyles, changing economic circumstances or simply uncertainties about the development of certain sectors. The most difficult segment of demand to define and forecast is the commercial sector. Various assumptions about demand in this sector could change commercial requirement forecasts substantially in the year 2000.

An emphasis on the conservation of energy within practical limits could reduce the standard forecast by as much as 20 per cent to 25 per cent by the year 2000. However some of the policies focused on anti-pollution regulations and environmental concerns, such as auto emission control and stack gas scrubbing processes would offset these reductions to some extent.

Changes in energy demand under different economic structure assumptions are difficult to estimate. If a very rapid rate of energy resource development is desired it is possible that some diminution of the growth in secondary industry may be necessary. Conversely, if the government encourages the rapid expansion of manufacturing industries, a somewhat slower pace of resource development may be necessary. Assuming that there will be some trade-offs necessary in these areas the total energy consumption in Canada, under different development patterns, is not expected to change substantially.

An important factor in this equation is the changing nature and location of our energy supply industry. For example, to carry large volumes of gas and oil from frontier regions very significant volumes of these products must be used by the pipelines themselves. In large diameter gas pipelines from the Arctic, pipeline fuel could equal 15 per cent of the total gas shipped through the line. In oil sands development, about one barrel in four is consumed in the extraction and refining process. Therefore, a high rate of resource development with greater reliance on frontier resources—including oil sands—would substantially increase energy use by the supply industry itself.

This use of energy by the energy industry would also apply if some of the alternative transportation modes for arctic oil and gas were eventually deemed preferable to conventional pipeline movements. For example, a railway movement of 2 million barrels/day of crude oil from the Mackenzie Delta to Edmonton would entail the consumption of about 20,000 barrels/day of locomotive diesel fuel. Similarly, if natural gas were to be liquefied and transported by rail or ship, the liquefaction process would consume about 15 per cent of the natural gas input.

On balance, considering major areas of uncertainty related to economic and social developments and possible changes in government policies, total energy requirements in the year 2000 could be about 25 per cent lower or as much as 15 per cent higher than the standard forecast.

Chapter 4

CANADA'S ENERGY RESOURCES

Canada has a large and diverse energy resource base including oil, natural gas, coal and uranium. Development of these resources will be paced by the movements of prices available for these energy commodities. This analysis assumes that international price trends will set energy prices within Canada.

The estimates of Canada's energy resource base suggest that there is a more than adequate supply to cover foreseeable requirements to the year 2000. Under different estimates of resource potential and world price trends, moderate to large production surpluses could be available for the export market.

The greatest gap in the knowledge of the resource base relates to the petroleum potential of the frontier areas. Estimates of resources from these areas differ by as much as 40 per cent. Our knowledge of this vast area can only be improved by continued exploration programs by the oil industry.

The previous chapter dealt with estimates of Canada's long-term energy requirements. This chapter reviews Canada's resource potential for uranium, hydro, coal, natural gas, and petroleum, and draws conclusions about possible future supply conditions.

Canada's Uranium and Thorium Potential and Supply Conditions for Nuclear Energy

It is estimated that about 400,000 tons of known resources of U_3O_8 can be made available in Canada at prices no higher than $15.00 per pound. Canada's cumulative domestic needs until the year 2000 will be about 100,000 tons while committed exports amount to 60,000 tons. Consequently, it is clear that, at this point, Canada has a significant surplus of low to medium cost uranium resource already proved or indicated. In addition to this resource base, Canada is believed to have a substantial undiscovered resource potential. Based on present knowledge, it is estimated that over 500,000 tons of additional potential resources of U_3O_8 could be developed for availability at less than $15.00 per pound. By about the year 2000, when the price for uranium could be within the region of $10.00 to $15.00 per pound, large unassessed potential will probably still exist in Canada. Over the very long term, well into the 21st Century, the price could climb to the point where it could become profitable to recover the uranium present at concentrations of a few parts per million in a variety of relatively common rock types.

The cost of uranium, however, plays only a minor role in the total cost of nuclear power. For example, even if the price of uranium increased almost ten-

fold, the impact on nuclear power cost would be relatively small. Today, for instance, a Canadian CANDU reactor can produce electricity for 7 mills per kWh with uranium costing $6.00 per pound. If uranium costs were $50.00 per pound, the electricity cost would only increase by 2 mills per kWh.

It can therefore be concluded that uranium is available to Canada in large quantities. By utilizing such uranium in present CANDU systems, and in future more advanced designs of heavy-water-moderated reactors, it is safe to conclude that Canada will have ample electricity available at reasonable cost for at least the next century.

In addition to the large uranium reserves and potential in Canada, there is a substantial quantity of thorium available as well. The thorium reserves associated with uranium in the $10.00 per pound U_3O_8 category have been estimated to exceed 100,000 tons ThO_2. Although little thorium is being utilized in nuclear power reactors at present, its use could grow as mixed thorium-uranium fuel cycles are developed in future decades for advanced CANDU reactors.

Canada's Hydro Potential and Some Other Sources to Generate Electricity

In the past most regions of Canada possessed convenient sites for the development of electrical energy from hydraulic sources at costs which in many cases were lower than most other developed countries in the world. Few hydraulic sites remain to be developed which are likely to offer electrical energy at dramatically low cost on a world competitive basis.

Some regions in Canada, notably British Columbia, Manitoba with the Nelson River project, and Quebec with the James Bay project, do possess undeveloped hydraulic resources competitive with nuclear power. Hydroelectric energy output might double in the next two decades, from a yearly delivery of about 150 billion kWh in 1970 to about 300 billion kWh in 1990. However, it is unlikely that significant capacity will be added afterwards because of competition from nuclear power.

Similarly, it is unlikely that new sources of electrical generation will contribute significantly to electricity production over our forecast period. This includes sources such as solid waste, farm waste, solar radiation, tidal power, geothermal power or wind power.

Canada's Coal Potential and Cost Supply Conditions

Canada has extensive coal reserves estimated at about 120 billion tons, of which about 118 billion occur in the three western provinces of Saskatchewan, Alberta and British Columbia, estimated as follows:

Saskatchewan	12 billion tons
Alberta	47 billion tons
British Columbia	59 billion tons
	118 billion tons

The remaining coal reserves occur in Nova Scotia and the Yukon and Northwest Territories. Smaller deposits also exist in New Brunswick and at Onakawana in Ontario, south of James Bay. Current mining operations are conducted in the three western provinces, Nova Scotia and New Brunswick.

Coals are classified into several ranks as determined largely from their carbon and heat content. Lowest in rank is the geologically youngest coal, lignite, followed in ascending order by sub-bituminous, bituminous and finally anthracite. Commercial value is not always determined by rank and some of Canada's most viable coal operations are based on lignite and sub-bituminous coals.

The Maritime coals are all bituminous in rank but those of Western Canada are not only vastly more abundant, but are of greater variety and of lower sulphur content. The geological estimate of western coals can be subdivided as follows:

Lignite coal	13 billion tons
Sub-bituminous coal	10 billion tons
Bituminous coal	95 billion tons
Total Western Canada	118 billion tons

The bulk of the lignite coal exists in Saskatchewan, approximately 12 billion tons of the total estimate of 13 billion tons. All of the sub-bituminous coal occurs in the prairie regions of Alberta. The amounts of anthracite are too small to show up in the tabulation.

Although these estimated reserves of lignite and sub-bituminous coals are large, they are greatly exceeded by the geologically older bituminous coal which constitutes the bulk of Canada's coal reserves. The estimate of 95 billion tons has been further subdivided into 86 billion tons of medium and low volatile bituminous coal and 9 billion tons of high volatile bituminous coal. Much of these reserves of medium and low volatile bituminous are of good metallurgical quality, as are also the high volatile coals.

The bituminous coals lie in both Alberta (37 billion tons) and British Columbia (58 billion tons).

It must be noted that all the above tonnages are geological estimates of coal based on *known reserves* plus that coal which can reasonably be expected to exist. An economic inventory of Canada's coal reserves to estimate how much of this coal might be economically extracted under known mining technology is currently underway. As might be expected, this inventory based on economic mineability, is a stricter measure than one based on geological occurrences and consequently tonnage estimates are substantially lower. Even on this more demanding basis, however, it is apparent that Canada has sufficient mineable coal for the foreseeable future, even at substantially greater production levels.

Information available to date indicates the following economically mineable reserves:

For Saskatchewan, approximately 292 million tons of lignite. It is expected that this actually measured tonnage will probably be significantly increased by the jointly sponsored program of exploration now being conducted by the

Governments of Canada and Saskatchewan. The current production of lignite in Saskatchewan is approximately 3.3 million tons per annum.

For Alberta, approximately 1.5 million tons of sub-bituminous coal have been delineated and evaluated as economically mineable. This amount represents most of this prairie coal that can be extracted by surface mining. The current production of sub-bituminous is approximately 4.9 million tons per annum.

The above main deposits of lignite and sub-bituminous coal have an aggregate proved total of approximately 1.8 billion tons for the continuing support of electric power generation on the prairies at prices between 15 cents and 20 cents per million Btu's. This is more than competitive with oil, natural gas or foreseeable nuclear power. Further resource evaluation in Alberta should prove the existence of additional reserves, recoverable primarily by underground mining at prices ranging between 25 cents and 45 cents per million Btu's. Coal at these latter prices has good future potential. There are also smaller but still substantial deposits of lignite coal at Hat Creek, British Columbia (about 340 million tons) and at Onakawana, Ontario (240 million tons).

Regarding the massive tonnages of bituminous coal in Alberta and British Columbia there is, as yet, insufficient knowledge on which to base a firm estimate of economically recoverable coal. A comprehensive and detailed investigation is required involving not only mining conditions and mining costs, but also a full evaluation of markets and revenues. Broadly, coal deposits of high metallurgical quality and reasonable mining conditions will be recoverable under current technology, but mining costs can be expected to be relatively high, in the order of 50 cents per million Btu's.

The Maritime coal reserves have been extensively mined over the past 170 years and most of the readily accessible coal has been extracted. In New Brunswick, operations are now limited to a single, very thin coal seam with recoverable reserves in the order of 3 million tons. It is of local value only to nearby electrical utility stations. In Nova Scotia, virtually all of the coal mining is being conducted in the sub-sea collieries of Cape Breton Island. These old and extensive mines are not economic but some possibilities exist elsewhere in this Sydney coal field for opening new and more efficient collieries. The field contains approximately 100 million to 150 million tons of coal reserves. Some of these coals are of marketable quality and may be economically recovered through new openings at the coast line but could not support the present labour force. One new colliery, the Lingan mine, has recently been opened.

Canada's Oil and Gas Potential and Supply Conditions

The major difficulty in determining Canada's oil and gas potential is that a number of factors are highly uncertain. In the case of coal, hydro and nuclear energy, there is a good degree of confidence about the supply conditions over the long term. In the case of oil and gas, there is a considerable uncertainty about how large the oil and gas resources actually are because most of these resources have not yet been discovered and are only inferred through knowledge of the geology of potential petroleum basins shown in Figure 1. Further, there is considerable uncertainty about how much of the potential will become available at different price levels,

CANADA'S PETROLEUM BASINS

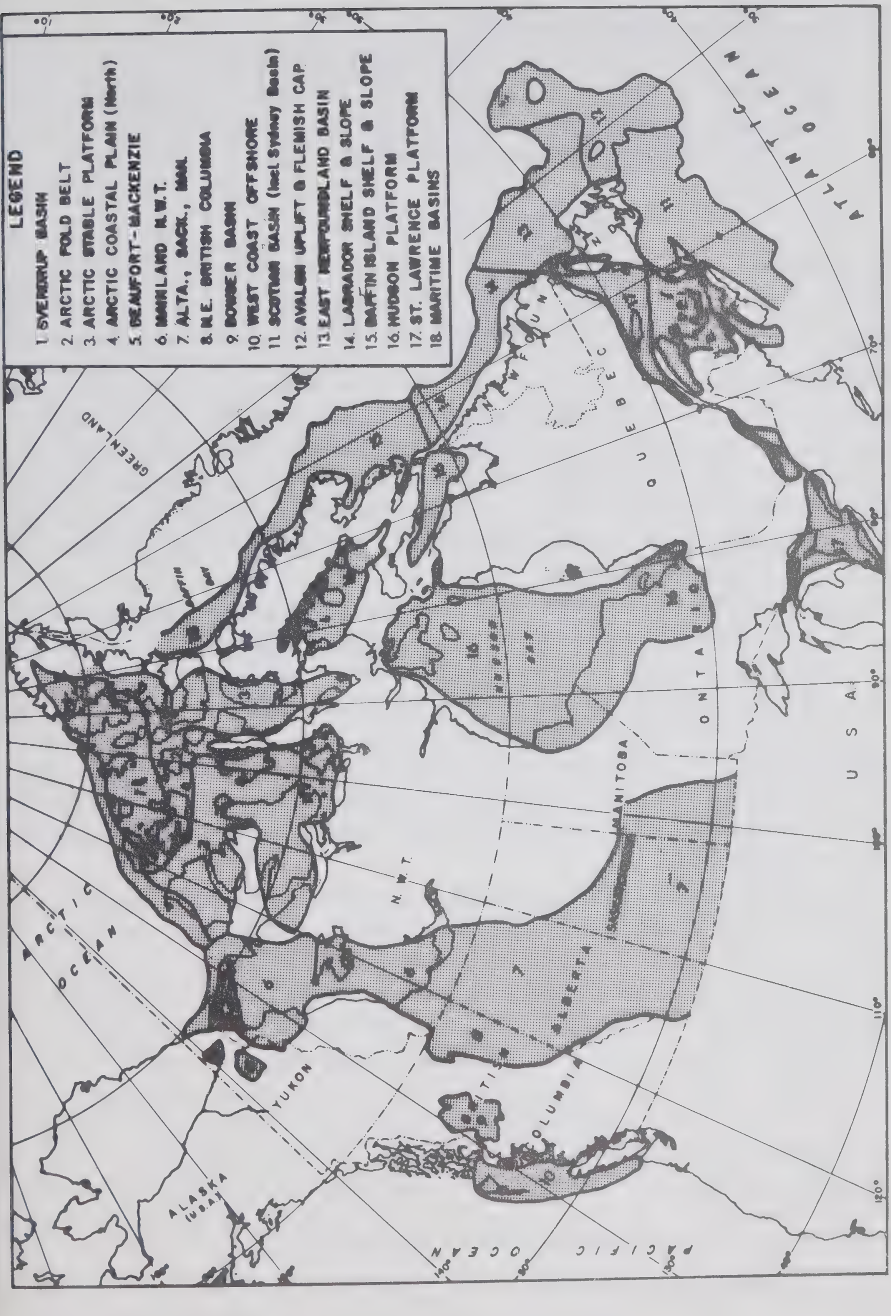


Figure 1

and finally, there is uncertainty about the pace at which the petroleum resource base can be discovered and developed. This high degree of uncertainty demands that special attention be directed to these energy sources.

There are four basic questions:

What is the resource potential?
How much of this potential might become available at various prices?
What could be the pace of discoveries and resource development?
How does the estimated resource availability compare to the standard forecast of oil and gas demand in Canada?

Resource Potential

Canada's petroleum resource potential can be grouped in three categories. Conventional oil, other resources such as oil sands and heavy oils, and conventional natural gas. All three resources are discussed with the help of Tables 1, 2 and 3.

Conventional Oil. As is shown in Table 1, proved reserves of oil *in place* totals 44 billion barrels. However, only slightly more than one third—or 16 billion barrels—of this discovered oil in place is recoverable under present technological and economic conditions. Of this 16 billion barrels, 6 billion barrels has already been produced and, consequently, Canada has about 10 billion barrels of proven oil resources remaining. These reserves occur almost exclusively in the provinces of Western Canada—mainly in Alberta.

It is believed that most of Canada's ultimate potential for conventional oil remains to be discovered. A large proportion of these resources will be found in Canada's frontier areas, such as the continental shelves and slopes and the Arctic areas onshore and offshore. Relatively little exploration has been conducted in these areas until very recently. Most current exploratory drilling is concentrated on the Scotian Shelf, the Grand Banks, the Mackenzie Delta and the onshore areas of the Arctic Islands. Little or no activity is occurring in other areas. With such limited information, it is difficult to make an accurate estimate of Canada's ultimate potential for conventional oil.

The Geological Survey of Canada (GSC), however, has begun a program of regular estimates of Canada's oil and gas potential. These estimates are based on a geological analysis of all the sedimentary basins in Canada and make use of comparisons with other petroleum producing basins throughout the world. Potential resource estimates for Canada will change from year to year depending upon new exploration results and upon an increasing insight into the geology and the petroleum history of the areas. Estimates from one year to another may, therefore, change continuously and considerably. However, each year's estimate will be based on the best geological knowledge at that particular point in time.

The potential conventional oil and gas resources outlined in the tables is the total oil and gas that might be produced by conventional means without any technological or economic constraints. Most of the analysis in this report was based on a GSC estimate (Estimate I—1972) that was submitted in 1972. These figures are given in Table 2. Recently the GSC prepared a more detailed estimate (Estimate II—1973) and in general their latest data are lower than the 1972 estimate.

Table 1

CANADA'S OIL AND GAS RESOURCES

	In Place	Recoverable		Cumulative Production	Remaining	
1. Proved Oil Reserves (Conventional)[1,2] Billion Bbls						
NWT	0.5	0.1		<0.1	<0.1	
W. Canada	43.8	15.9		6.2	9.7	
E. Canada	0.2	0.1		<0.1	<0.1	
Subtotal	44.5	16.0		6.3	9.7	
2. Proved Natural Gas Reserves[2,3] Trillion Cu. Ft.						
NWT	2.0	1.3		—	1.3	
W. Canada	116.5	69.1		17.8	51.4	
E. Canada	1.1	1.0		0.7	0.3	
Subtotal	119.6	71.5		18.5	52.9	
3. Potential Oil (Conventional) Billion Bbls		4	5		4	5
Arctic Islands and NWT		70	28	—	70	28
W. Canada (Provinces)		6	5	—	6	5
East coast		42	50	—	42	50
Subtotal		118	83	—	118	83
4. Potential Natural Gas, Trillion Cu. Ft.		4	5		4	5
Arctic Islands and NWT		481	342	—	481	342
W. Canada (Provinces)		101	44	—	101	44
East coast		253	326	—	253	326
Subtotal		835	712	—	835	712
5. Alberta Oil Sands[6] Billion Bbls						
Open-Pit Mineable		65		0.1	65	
"In-Situ" Recovery		236			236	
Total	710.8	301		0.1	301	
6. Alberta Heavy Oil[7] Billion Bbls	75.0	30.0		—	30.0	
7. Total Resource (BOE) Billion Bbls	—	616	561	9.5	607	551

Note: Totals may not add due to rounding.
[1]Includes natural gas liquids.
[2]Source: Canadian Petroleum Association (December 1972).
[3]Figures quoted for "In Place" gas are on a raw gas basis, all other are pipeline gas.
[4]Geological Survey of Canada (February 1972) estimates of ultimate recoverable potential less proved reserves.
[5]Geological Survey of Canada (March 1973) estimates of ultimate recoverable potential less proved reserves.
[6]Source: Oil and Gas Conservation Board, "A Description and Reserve Estimate of The Oil Sands of Alberta", October 1963.
[7]Source: "The Oil Sands of Alberta"—H. J. Webber, The Journal of Canadian Petroleum Technology, October—December 1967.

Although Estimate II predicted significantly lower oil potential than the earlier estimate, the gas potential estimate decreased only marginally. The new estimates, therefore, do have long-term impacts and policy implications that differ from those related to Estimate I. The fact that the figures for 1973 are lower than for 1972 does not necessarily mean that the figures for 1974 will be lower again. There is a chance that these figures will be higher or lower and both estimates are presented in the report to give an appreciation of the impact of changes of this magnitude. (Estimate II was completed early in 1973 and not all the economic analyses of it could be finished prior to the printing of this report.)

A comparison of the GSC estimates of 1972 and 1973 can be drawn from Table 2. The figures indicate a considerable reduction in the predicted oil potential from Arctic Canada and the NWT; down from 70.2 to 28.2 billion barrels. To some extent this is offset by an increase in the estimate for Eastern Canada from 41.8 to 50.5 billion barrels. Arctic, NWT and Western Canada gas potential estimates have decreased from 652.0 to 455.8 tcf. Again this is offset somewhat by an increase from 254.1 to 327.1 tcf for Eastern Canada. Overall, the oil estimate is lower by 35.2 billion barrels, or 26 per cent and the gas estimate is lower by 123.2 tcf or 14 per cent. The most significant factor in the lower estimate is that much of the decline in potential occurred in readily accessible areas which were previously expected to contain low to medium cost oil.

Other Oil Resources. Apart from conventional oil, Canada has a considerable resource in the Alberta oil sands. Approximately 710 billion barrels of oil are estimated to be in place, about 65 billion barrels of which may be recovered by open-pit mining techniques. A large portion of the remainder might be recoverable by a different extraction technique. In both cases, "recoverable" may imply higher prices and new technologies.

Natural Gas. Canada's proved natural gas reserves (*raw gas in place*) are estimated at 120 trillion cubic feet, of which 72 trillion cubic feet *of pipeline gas* is recoverable. Almost 19 tcf has already been produced, leaving 53 tcf of pipeline gas available.

All of these figures are shown in Table 1.

The Geological Survey estimates that in the western provinces, another 44 trillion cubic feet of gas can be found. In addition to these resources, considerable volumes of natural gas could be discovered on the east coast and in the Arctic. GSC Estimate I showed a remaining gas potential of 834 trillion cubic feet compared to Estimate II of 711 trillion cubic feet (Table 1).

Other Resource Estimates. Table 3 presents a comparison of four estimates of Canada's ultimate oil and gas potential. Although the figures are not completely comparable in that they do not coincide exactly as to areas included, depth of sediments considered, or water depth limitations on the continental margins, they do indicate reasonable agreement regarding Canada's overall oil and gas potential. (It should be noted that the Canadian Petroleum Association (CPA) estimate does not include what might be referred to as "currently unattainable areas", i.e. the continental slopes below 600 feet of water depth and the Arctic Islands, Beaufort Sea offshore area.) The Canadian Society of Petroleum Geologists' estimate (CSPG-A) does not include the resource potential that might be present in the

Table 2

COMPARISON OF 1972 AND 1973 CANADIAN OIL AND GAS RESOURCE ESTIMATES

Basin	Ultimate Recoverable Oil (Billion bbls.) GSC Estimates		Ultimate Recoverable Gas (Tcf) GSC Estimates	
	1973	1972	1973	1972
1. Sverdrup Basin				
Land	7.2	10.9	118.8	65.3
Offshore	4.7	8.7	79.2	52.2
2. Arctic Fold Belt				
Land	2.6	4.1	15.2	24.3
Offshore	1.1	4.2	6.8	25.0
3. Arctic Stable Platform				
Land	0.6	2.0	0.6	11.9
Offshore	0.6	2.7	0.6	15.9
4. Arctic Coastal Plain (North)	3.5	16.7	20.8	132.8
5. Beaufort-Mackenzie				
Land	3.5	2.6	50.0	20.6
Offshore	2.7	12.1	43.5	96.6
6. Mainland NWT	1.7	6.2	7.5	37.8
7. Alberta, Saskatchewan and Manitoba	18.3	19.8	82.2	88.5
8. N.E. British Columbia	1.6	1.4	21.4	49.1
9. Bowser Basin	—	0	5.6	24.8
10. Westcoast Offshore	0.6	1.2	3.6	7.2
11. Scotia Basin (including Sydney Basin)				
Shelf	3.7	5.8	28.0	34.0
Slope	5.5	3.9	42.1	23.4
12. Avalon Uplift and Flemish Cap				
Shelf	0.3	[1]	1.9	[1]
Slope	2.3		12.9	
13. East Newfoundland Basin				
Shelf	10.2	5.0	60.9	30.0
Slope	5.3	4.4	31.3	26.2
14. Labrador Shelf and Slope	5.5	5.1	38.7	30.5
15. Baffin Island Shelf and Slope	14.7	14.0	91.3	85.5
16. Hudson Platform	1.5	1.5	7.3	8.7
17. St. Lawrence Platform	0.6	1.2	3.6	10.2
18. Maritime Basins	0.9	0.6	9.1	5.6
Totals	99.2	134.4	782.9	906.1

[1]Included in total for East Newfoundland Basin.

continental slope sediments. In a more recent submission the Society presented a second set of estimates based upon an entirely different premise. This estimate (CSPG-B) is discussed in Appendix A.

Large differences, however, are apparent in the estimates for the individual areas. Largely because of these differences, considerable variations also occur in the estimates of the amounts of low- and medium-cost oil and gas that may ultimately be developed.

Supply Conditions for Petroleum

Conventional Oil. All of the proved reserves of conventional oil are recoverable at present market prices. In the frontier areas, only a relatively small fraction of the crude oil potential may be recoverable at current prices. More and more will probably become available if international prices increase to $4, $5 or $6 per barrel (all prices are expressed in constant 1972 dollars).

An economic analysis was carried out to determine what portion of the oil potential could become available at various price levels. This analysis considered exploration, development and producing costs and the cost to transport the crude oil to the main consuming areas. Costs, in this context, include a rate of return to the industry commensurate with the risks undertaken in such development. At today's prices, it is unlikely that sufficient oil will become available in the Arctic to justify the construction of a pipeline southwards to Canada's industrial heartland. It is also doubtful that large volumes of oil will come from the continental margins. For higher prices, however, large volumes could become available. For example, if the crude oil price reaches $5 per barrel, approximately 50 billion barrels of frontier oil could become available on the basis of resource Estimate I and approximately 25 billion barrels on the basis of resource Estimate II. The substantial difference between those two figures indicates that the new estimates of the Geological Survey have resulted in a significant reduction of potential low cost frontier oil.

For higher prices, more and more oil should become available. If oil prices were to increase to $8 per barrel, the available potential could reach almost 70 billion barrels according to resource Estimate I and almost 40 billion barrels according to resource Estimate II.

Estimates I and II, shown in Figure 2, illustrate the various volumes of crude oil that might be expected to become available at differing price levels. It is interesting to note that even at a price of $15 per barrel there are still estimated resources remaining to be developed because they require higher prices. This indicates that the potential resource estimate includes some very expensive crude oil.

Oil Sands and Heavy Oils. It is estimated that of the 65 billion barrels of oil sands that can be mined by open-pit mining methods, about 15 billion barrels will be available for $5 per barrel while 35 billion barrels should be recoverable for a price of about $6 per barrel.

It is still highly uncertain at what price level heavy oils could be made available, but it is likely that these costs will be higher than $5 and lower than $8, depending mainly on various geological conditions, depth of burial and oil content of the sand. It is likely also, that certain amounts of oil sands can be re-

TABLE 3

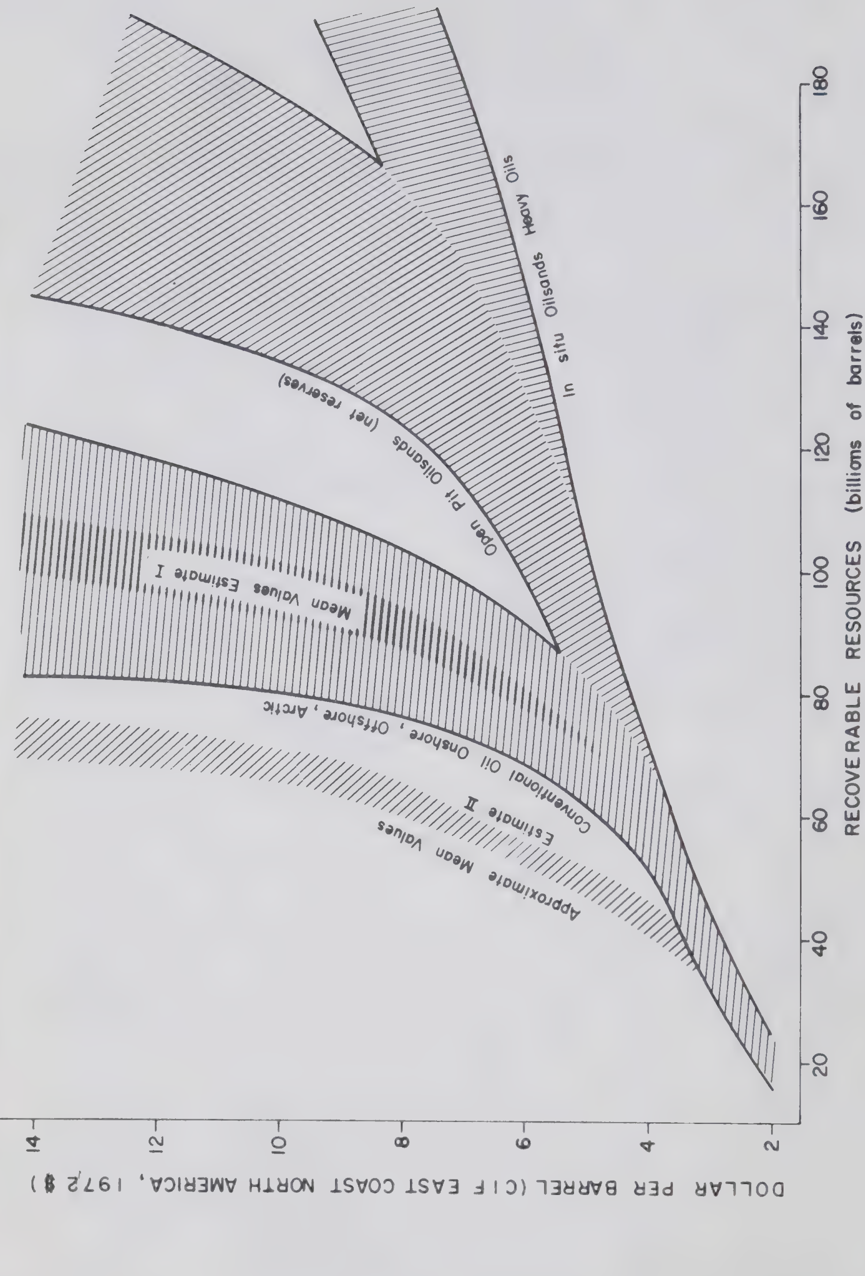
COMPARISON OF GSC, CPA AND CSPG ESTIMATES
(based on 1973 GSC regions)

	Oil Potential				Gas Potential			
	CPA 1969	GSC 1972 (Estimate I)	GSC 1973 (Estimate II)	CSPG(A) 1973	CPA 1969	GSC 1972 (Estimate I)	GSC 1973 (Estimate II)	CSPG(A) 1973
	Billions of Barrels				Trillions of Cubic Feet			
1. Arctic Islands and Coastal Plain (North)	43.5	49.3	20.3	28.6	260.7	327.4	242.0	208.8(1)
2. Beaufort Mackenzie	47.4	14.7	6.2	8.0	283.8	117.2	93.5	64.0
3. Western Canada		28.6	22.2	25.0		207.4	120.3	155.5
4. Offshore East Coast	24.8	38.5	47.5	22.1	149.9	229.6	307.1	132.6
5. Hudson Platform	2.9	1.5	1.5	(1)	17.4	8.7	7.3	(1)
6. Eastern Canada Onshore	2.3	1.8	1.5	1.5	13.0	15.8	12.7	16.6
Totals	120.9	134.4	99.2	82.5	724.8	906.2	782.9	577.5

[1]Potential for Hudson Platform included in Arctic Islands and Coastal Plain (North).

NOTE: Estimates all have slightly different basis in that areas considered, limit of depths of sediments or depth of water on continental slopes are not the same in every case. The derivation of each of the above sets of estimates is discussed in Appendix A.

SUPPLY CONDITIONS FOR OIL BASED ON RESOURCE ESTIMATES I AND II



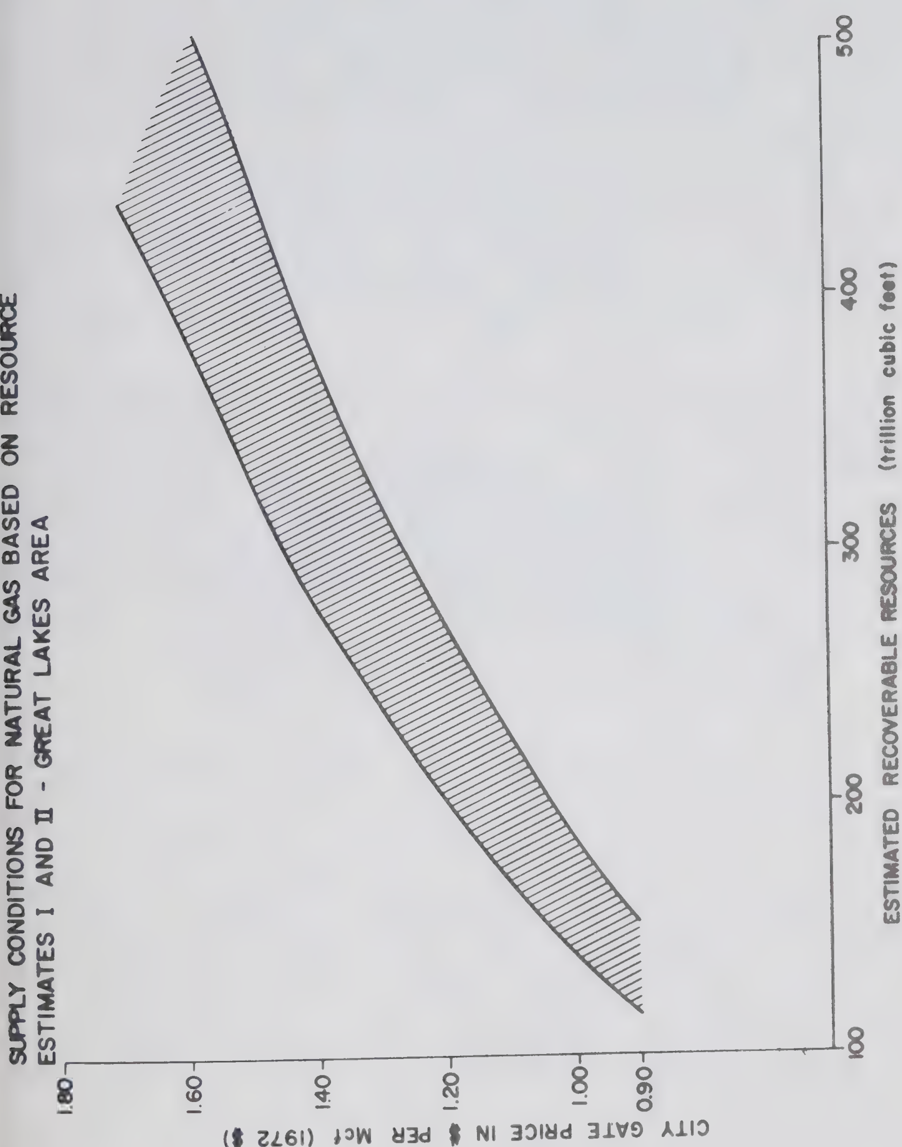

SUPPLY CONDITIONS FOR NATURAL GAS BASED ON RESOURCE
ESTIMATES I AND II - GREAT LAKES AREA
CITY GATE PRICE IN $ PER Mcf (1972 $)
1.80
1.60
1.40
1.20
1.00
0.90
100
200
300
400
500
ESTIMATED RECOVERABLE RESOURCES (trillion cubic feet)

Figure 3

covered by "in situ" techniques at prices between $5 and $8 per barrel. However, it is yet very uncertain how large the volumes are that can be recovered for such prices. Figure 2 also indicates the total recoverable oil from oil sands at various price levels.

Natural Gas. The presently proved reserves of natural gas will all be available at current costs. This is not to suggest that current prices will not increase. City gate prices in the Great Lakes area are now in the range of 40-45¢ per MCF. It is likely that the amount of available gas could triple if these prices increase to about $1 per MCF at the city gate. Most of the increase should come from frontier resources. Even larger additions can be expected if the price increases to $1.25 per MCF because, under those conditions, the large gas potential estimated to exist in the Arctic Islands should become available.

In total, it is estimated that approximately 250 trillion cubic feet of natural gas could be available to Canadians for a price of $1.25 per MCF. If the price were even higher then again substantial additions can be expected. At a price of $1.60 per MCF, approximately 450 trillion cubic feet may become available in total.

These figures are all based on Estimate I but will not change significantly in the case of Estimate II. In fact, for Estimate II, a first approximation indicates that Canada has more inexpensive gas than originally was anticipated. Estimate II indicates that Canada might have approximately 275 trillion cubic feet available for $1.25. Although the total resource base declined somewhat, the volume of relatively inexpensive gas was estimated to be somewhat higher. Consequently, whether we take Estimate I or II, it appears from these projections that Canada can anticipate the development of substantial quantities of natural gas. Figure 3 illustrates projected supply conditions for natural gas at various price levels.

Chronology of Discovery and Development

A basic question is whether Canada will be able to satisfy its own future requirements from the standpoint of production capacity. Further, how much oil and gas might be available for export markets? The fact that a certain amount of oil or gas reserves can be developed at a certain price does not automatically lead to the conclusion that it can be produced within a specific time frame. Fields must be developed according to good engineering practice. A reasonable lead time is required before a complete petroleum basin can be brought into production.

Estimates of total basin production capability were made based on anticipated discovery success ratios and advances in technology so as to obtain an insight into the maximum production capacity that might be developed. Figures 4 and 5 show possible production capacity curves for crude oil in Canada under two different price assumptions. Figure 6 illustrates a possible production curve for natural gas. These resource projections are compared with Canadian demands as estimated by the Standard Forecast described in Chapter 3.

Figure 4 projects production capacity for the case where oil prices increase to $4 per barrel (1972 dollars) and remain at that level. Figure 5 treats the $6 per barrel case. The natural gas curve assumes a city gate price of $1.25 per Mcf with no further increase. It is not probable that prices will flatten at a certain

level, but these curves give some insight into the importance of price in the development of the Canadian frontier.

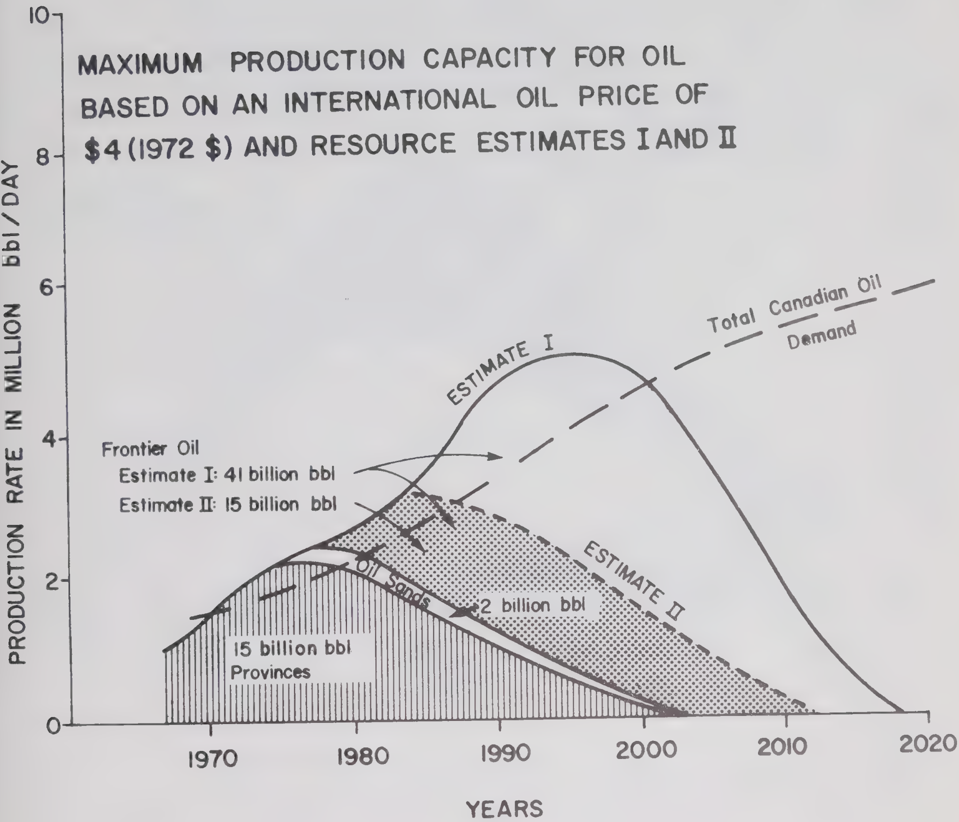


Figure 4

In the case of oil, Estimate I indicates a substantial resource surplus in the $6 case prior to the period 2010-2020. A rough approximation of the supply under Estimate II however shows a substantial decrease in the amount of oil that might be in excess of domestic needs. However, a significant part of the $6 oil supply is derived from oil sands, the estimates for which are not influenced by the lower GSC Estimate II. This question will be considered again in the next chapter.

A serious situation could develop if international prices rise to $4 per barrel and stay roughly at that level (in constant 1972 dollars). Estimate I would indicate a reasonably small oil surplus up to the year 2000. Estimate II shows that at that price Canada might not be able to satisfy her own total demand much beyond 1985. This result is partly due to the fact that oil sand plants will probably not be built unless prices exceed $4 per barrel. The probability of prices staying below $4 is considered to be extremely low.

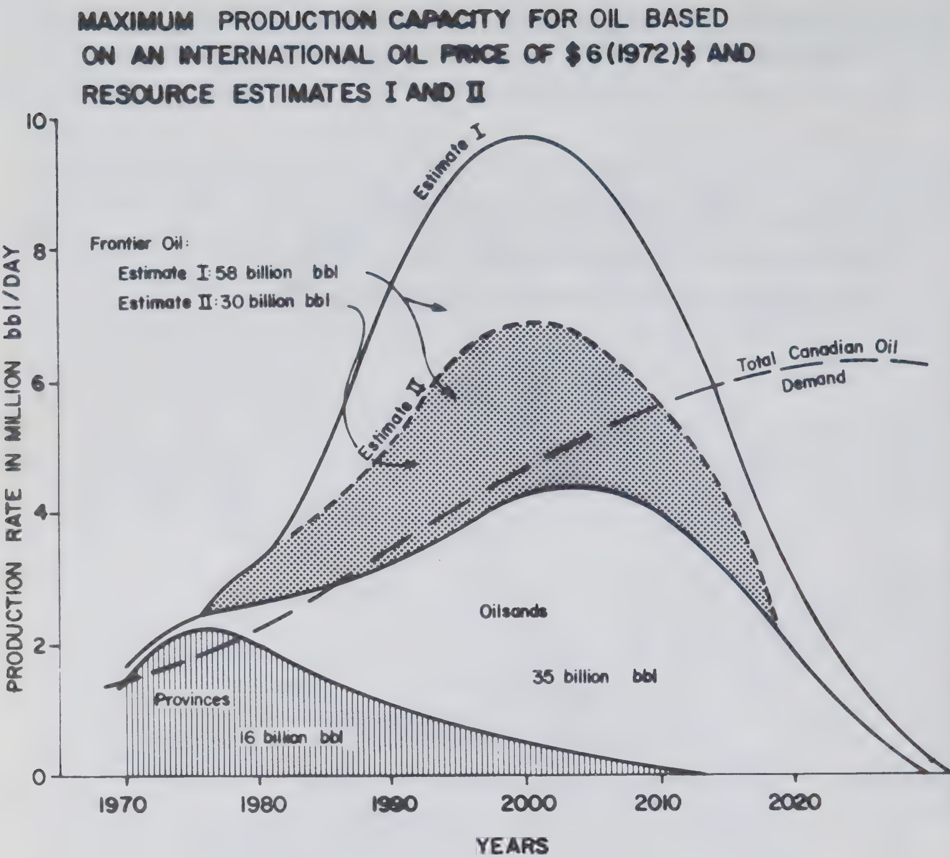


Figure 5

Throughout this chapter, emphasis has been placed on the long-term situation. Examination of the short-range outlook (i.e. the 1970's) for oil supply was recently carried out by the National Energy Board. That examination showed that both the domestic and the very rapidly increasing export demands could not continue to be met without serious reduction in the reserves required to supply future Canadian requirements. Although it is expected that increased production will become available from both the frontier areas and the oil sands by the late 1970's, such reserves can not be relied upon for meeting firm requirements within the short range. Accordingly, on February 15, 1973, the federal government announced crude oil export controls to become effective on March 1, 1973. The policy statement announcing these export controls is included in Appendix C. In making the announcement the Minister stated that the amendments to the National Energy Board Regulations were interim in nature. Public hearings will be held by the Board to determine the appropriate methods for protecting the public interest in respect of oil exports over the longer term.

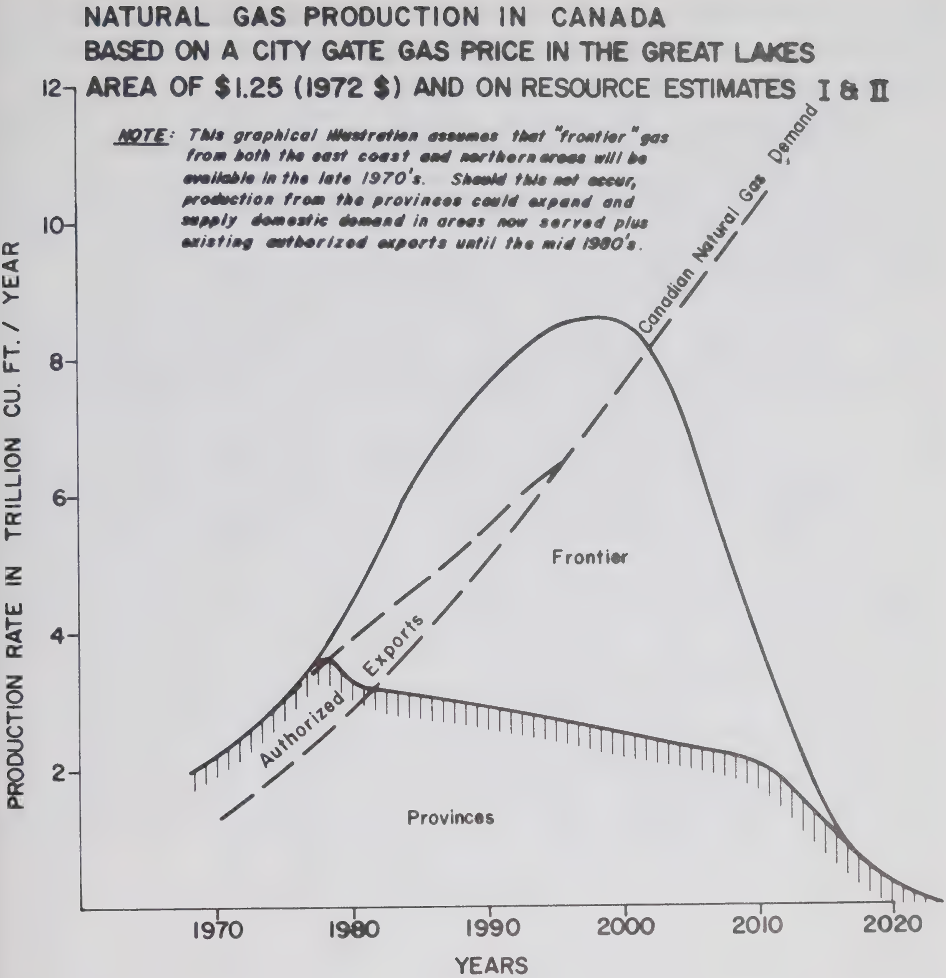


Figure 6

In the case of natural gas, exports have been controlled by the National Energy Board since 1959. A number of export licences covering rather substantial volumes of gas were granted by the Board over the years. In August 1970, applications for additional exports were reduced and in November 1971 further exports were denied because surplus reserves, as determined by the National Energy Board's formula, were not then available. The present volume of reserves is sufficient to meet existing export commitments and growing Canadian demands in the areas now served through the 1980's. However, by the mid-1980's the production capability of these reserves, rather than the reserves themselves, becomes a limiting factor. Therefore, an increasing proportion of the total growing requirements must be supplied from new reserves either in the frontier areas or in

the present established areas of gas production. Thus it is likely that additional gas exports, if any, will be minor until large scale gas reserves and production from the frontier areas have become clearly established.

In summary, more than adequate coal and uranium reserves at reasonable prices are available to meet projected Canadian needs to the year 2000 and beyond. In the area of oil and natural gas resource potential, however, the situation is not as clear. Much will depend not only upon the success in proving up the resource estimates contained in this report, but also in the movement of oil and gas prices. Clearly, the greater the price the greater our possible reserves.

The estimates of oil and gas resources are obviously very preliminary in nature. The differences between the 1972 and 1973 estimates are indicative of the kinds of changes which may be experienced as further studies and exploration work is carried out. Such estimates help in long-term assessments of policy directions, but the policies themselves must be largely predicated on the reserves which have actually been proven. This reveals the conundrum; it is exploration by the petroleum industry which will find these reserves, but the industry naturally wishes to exploit them when they are found—not let them remain in the ground as reserves for a future generation. If a petroleum reserve is to be determined and retained for future domestic use, the exploration costs accumulate interest and the end cost of the resource, when developed, must reflect that financial burden.

Industry may only be interested in exploring for and developing reserves if an early return on capital investment is possible. In addition, it should be noted that the economic transportation of oil and gas from the far north may well depend on incremental markets larger than those available in Canada and thus some export may be essential. This would decrease the surpluses over Canadian demand suggested by the graphs contained in this chapter.

Chapter 5

A LONG-TERM SUPPLY-DEMAND PROJECTION

Projection of Canada's energy needs to the year 2050 can be nothing but the very roughest of approximations. Consider the changes which have taken place in the past 80 years.

By 2050 electrical energy could provide 90 per cent of all energy needs. Cumulative demands on natural gas could total 500-600 trillion cubic feet. The total use of all fossil fuels will probably begin to decline in the period 2020 to 2030.

Under the assumptions adopted for both the demand and the resource calculations Canada would have adequate energy resources to meet its own needs at prices competitive with expected world prices. The volumes available for export will depend heavily on exploration successes in the frontier areas and new oil sand technology.

Concern is often expressed about the availability of fossil fuels or energy in general in the very long term. This chapter evaluates Canada's possible energy demand and supply situation in the long term and on the basis of Canada's own resources. Particular attention will be given to supply and demand of liquid petroleum products.

Widely ranging opinions exist about the long-term development of Canada's population, economic growth, total energy consumption, various possibilities for technological developments and the need for energy conservation. Recently, arguments have been put forward that favour zero population and economic growth. Some scientists predict a gradual shift from conventional fuels to new sources of energy such as solar power. Others claim that the conventional energy sources including nuclear power will prevail. However, one can pose the question whether Canada has enough resources—and for what price—to cover Canadian needs under two assumptions which are felt to be conservative.

A continuing strong growth of energy demand in Canada until the year 2050.

No new technologies or new sources of energy except "in-situ" oil production from the oil sands and coal gasification and liquefaction. (Coal processes are more or less proven technologically with our long-term price forecast.)

A continuing growing energy demand was developed on the basis of the following criteria:

Canada's population in the year 2050 would be 2½ times the population today (1970) or approximately 55 million people.

Energy consumption for residential use would increase five-fold, or the energy use per capita would double. (This is a very high assumption if one realizes that the energy use per household has not changed substantially in Canada for the last 10 years.)

Energy demand in marine transportation would increase five-fold.

Energy demand for road and rail transport would increase seven-fold. (This increase is relatively modest in comparison with the trends until the year 2000, but it was assumed that thereafter a rather significant change from road to rail traffic would take place that would satisfy a larger transport requirement with less energy.)

Industrial use was estimated to increase about fifteen-fold.

Non-energy use of fuels would grow more rapidly than the industrial use and would increase twenty-fold.

The commercial sector would expand twenty-five-fold.

The most rapidly expanding sector would be air transportation which would increase one hundred-fold.

The high increases for non-energy uses and air transportation were included because it is frequently thought that the air transportation market and the use of fossil fuels for petrochemical purposes are the two markets where electricity cannot easily replace this form of energy use. On balance the above growth predictions are considered to be high.

With regard to the division of the market between electricity and fossil fuels, it was assumed that electricity would gradually replace all the markets where energy is currently used for heating purposes, which means heating for homes as well as industrial boilers. It is interesting to note that this could reduce the needs for natural gas, for energy purposes, to virtually zero in the year 2050; natural gas would only be used for petrochemical purposes at that time. Electricity would also provide energy for most land transportation in the form of rail traffic and electric cars.

An earlier chapter of this Section has indicated that Canada's large uranium potential, combined with the characteristics of CANDU reactors which minimize the impact of increased uranium prices, work together to ensure future supplies of nuclear energy at reasonable prices. The large expansion projected for nuclear energy could be satisfied with the existing CANDU reactor. However, once further advances in the CANDU concept have been made on plutonium recycling and thorium utilization, the availability of uranium and thorium should ensure self-sufficiency in fuel supplies in Canada for centuries. Obviously, the challenges posed by such a major increase in nuclear generation would have to be met. Such concerns relate primarily to environmental problems associated with waste heat and nuclear waste disposal.

Figure 1 illustrates the possible energy demand pattern over the next 80 years to the year 2050. Electricity could provide about 90 per cent of all energy requirements in the year 2050. The projection shows clearly the gradual development of the "electrical society".

The total amount of natural gas that will be needed to satisfy the projected demands would range from 500-600 trillion cubic feet. The prices necessary to bring forth this supply from Canadian conventional resources would have to be in the \$2-\$3 per Mcf range by 2050 (constant 1972 dollars). If, however, this conventional gas is not competitive at these price levels, cheaper gas might be made from

coal, or gas would be replaced by electricity or oil. Concerns about long-term natural gas availability are mitigated to some extent as electricity can be substituted for gas in most uses.

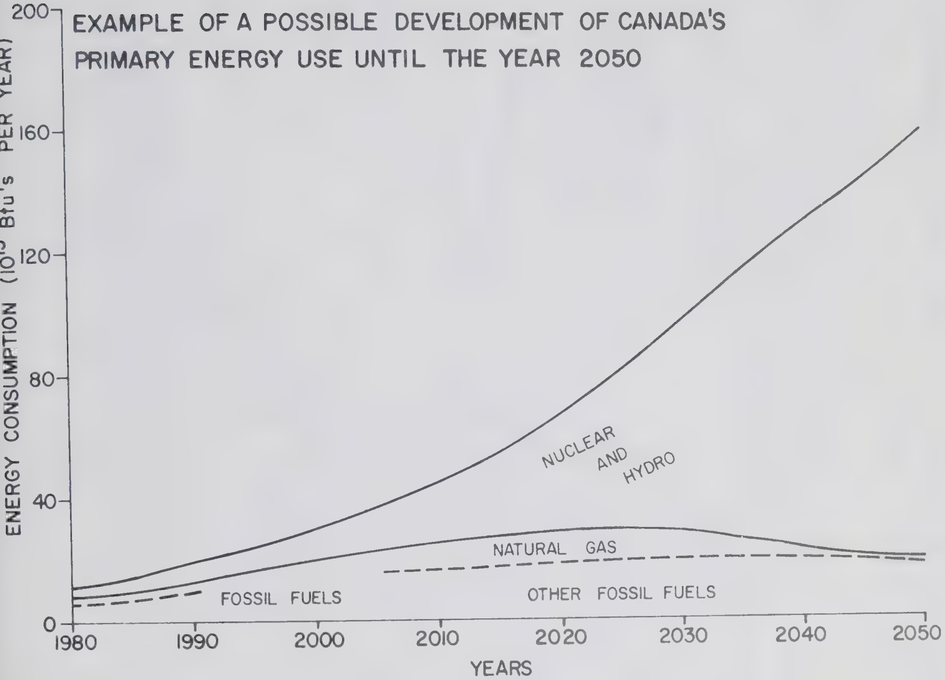


Figure 1

To evaluate the possible Canadian oil production and consumption in this context, Figures 2 and 3 were developed. Figure 2 is based on the GSC Estimate I and Figure 3 is based on the later Estimate II. Under both estimates of resources, Canada could satisfy her oil demand to beyond the year 2000 on the basis of Canadian conventional oil and oil sands mined by open-pit methods. After that, in both cases, "in-situ" oil sands and oil from coal would have to be made available in addition to more conventional oil and open-pit oil sands at prices up to $8 per barrel.

Oil and gas resource Estimate I suggests that Canada may have an enormous potential surplus above its own requirements. In the case of resource Estimate II this estimated surplus has diminished considerably, from about 5 million barrels a day surplus capacity in the year 2000 to about 1½ million barrels a day. As mentioned earlier, the geologic estimates are subject to great uncertainty—as are costs and prices—and there is, consequently, a chance that the actual resource potential

EXAMPLE OF A POSSIBLE DEVELOPMENT OF CANADA'S OIL PRODUCTION AND CONSUMPTION UNTIL 2050 BASED ON RESOURCE ESTIMATE I.

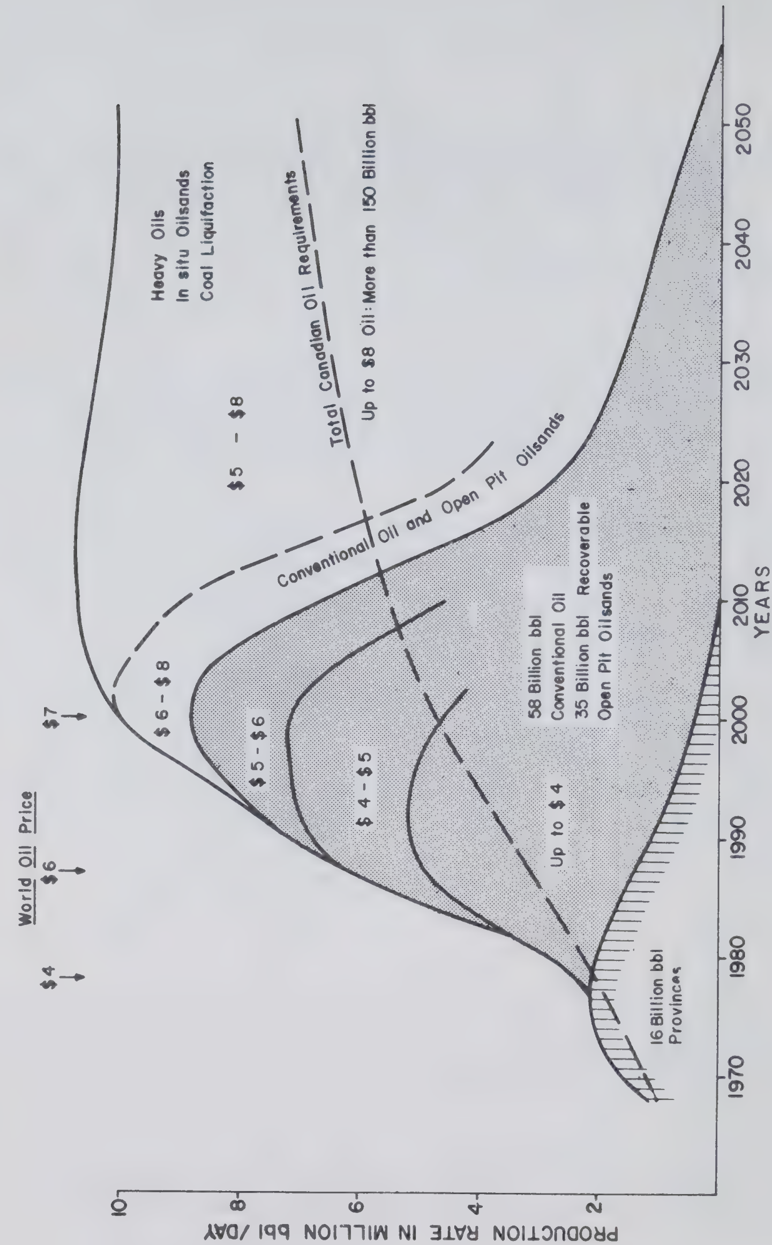


Figure 2

EXAMPLE OF A POSSIBLE DEVELOPMENT OF CANADA'S OIL PRODUCTION AND CONSUMPTION UNTIL 2050 BASED ON RESOURCE ESTIMATE II.

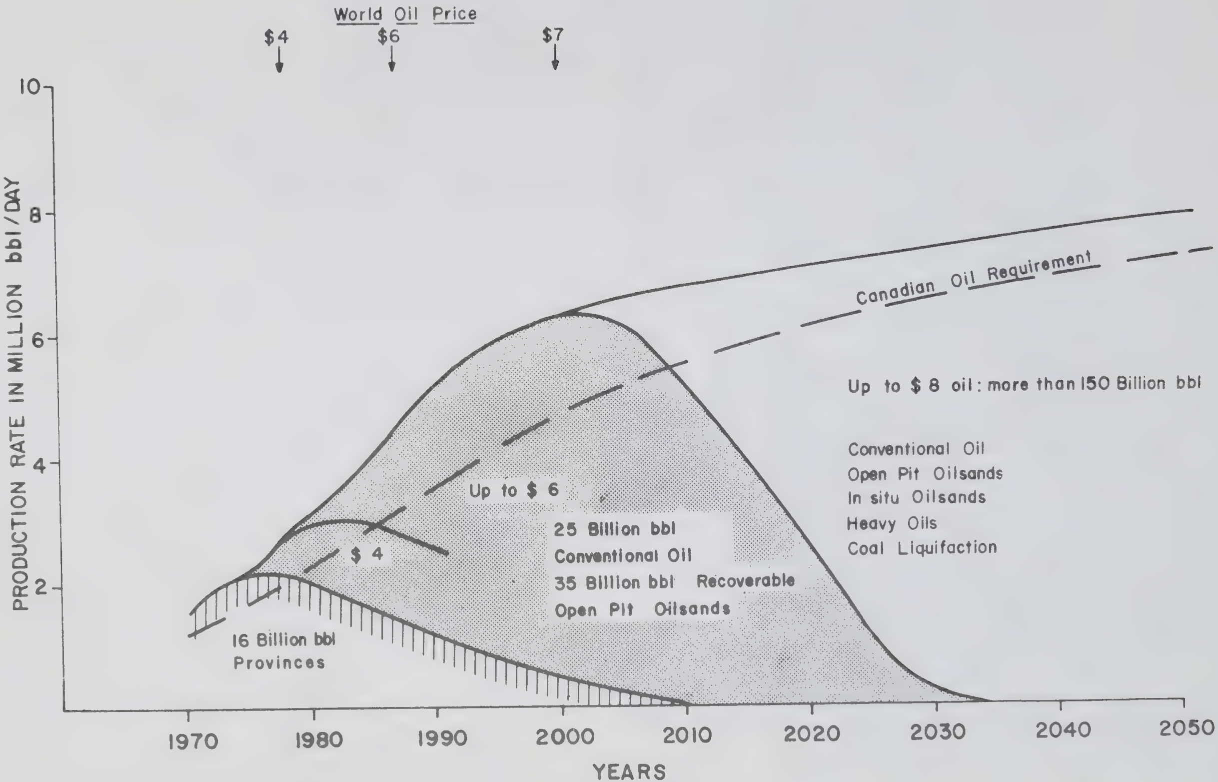


Figure 3

will be less than the estimate made by the Geological Survey to such a degree that Canada could not satisfy her own needs until the year 2000—within the economic constraints of expected world prices. Obviously, further work needs to be done to assess the magnitude of this possibility and to evaluate the consequences that this could have for policy decisions.

Whether or not Canada has a large surplus, a small surplus, or no surplus at all, it is evident from both graphs that Canada should not physically run out of oil. The volumes of oil that can be made available from synthetic sources are so large that there is little question that Canada can satisfy her own needs easily until the year 2050 at oil prices reaching $7 or $8.

In summary, the analysis suggests that Canada has more than enough energy resources available to cover her own use at least until the year 2050 and that there is a chance that there may be substantial amounts of oil and gas surplus to domestic demand. The nature of the development outlined assumes prices in the year 2050 would not exceed (in 1972 dollars) 10 mills per kWh for electricity, about $2 per thousand cubic feet for natural gas and about $7 or $8 per barrel for oil.

Chapter 6

INTER-ENERGY COMPETITION

Nuclear power generation will expand rapidly and become a major source of electrical energy. In central Canada, nuclear power is now the cheapest new source of electrical energy for base load operations. Hydroelectric energy could expand to about twice its present level. Coal will continue to play a major role in power generation in the Prairie Provinces.

In the large industrial areas of Ontario and Quebec, Canadian natural gas—priced on the basis of fairly stable long-term contracts—competes with imported heavy fuel oil priced in line with international competition.

The share of natural gas use in the industrial market will depend on competitive fuel prices in the future. In view of the substantial fuel oil price increases that are expected, relatively large price increases in natural gas should not result in a large loss of its market share.

Two areas of competition are analysed in this chapter, competition between various fuels to supply electricity, and competition between oil and natural gas.

Competition in the Electrical Market

Many factors have to be taken into account when deciding whether nuclear, thermal (based on fossil fuels), or hydro power is the economical energy source to produce electricity.

In the first place, the competition pattern varies greatly from one area of Canada to another. Currently, electrical generation on the basis of fuel oil is favoured in most cases in the Maritimes; in Quebec new electrical generation will likely be centred around the development of hydro in the James Bay area; in Ontario coal, oil and nuclear power are in competition; in the western Prairies, coal and natural gas compete; while in Manitoba and British Columbia hydro power is the most common source of electrical generation. The reasons for these differences are geographical conditions that make hydro power available in Newfoundland, Quebec, Manitoba and British Columbia, and the supply conditions for the various fossil fuels.

Secondly, electrical generation costs are significantly influenced by the size of the system load. If the market area is sufficiently large and concentrated, large generating plants with large capacity units can be interconnected with a transmission network and significant economy of scale can be achieved.

Thirdly, in meeting the demands placed on electrical power systems it must be recognized that electrical energy consumption varies on daily and seasonal cycles. The supply network must be designed with a capacity to meet the peak requirements as well as the base or continuous load. This results in some generation facilities being specifically designed to operate economically on peaking duty while others are specifically designed for base load operation.

In the Maritimes the size of the electrical system, for some years, will restrict the size of the largest generator that can be economically employed. While coal has been used to a significant degree, especially in Nova Scotia, new generating plants are likely to be fuelled by oil at prices which are lower than in most other areas of Canada. By the early 1980's system growth, along with electrical interconnections with other systems, should permit the installation of generator unit sizes large enough to justify economical nuclear stations. If large offshore gas discoveries are made it might become appropriate to employ gas on a temporary basis in generating stations pending development of other markets.

In Quebec, the James Bay Power Project will probably produce electricity at less cost than power available from the consumption of fuel oil. If fuel prices reach 60¢ per million Btu in 1980, and it is likely that they will exceed that level, the James Bay development will provide electricity to the Montreal market for about 1 mill per kilowatt hour cheaper than fossil fueled thermal power. James Bay hydro is also expected to be somewhat lower in cost than nuclear power when the total costs of providing for a system load factor of 60 per cent are taken into account. In the late 1980's however nuclear power will penetrate the Quebec market to a large and increasing extent.

Since the demand for electrical energy in Ontario is expected to remain at close to the present annual load factor of about 60 per cent, nuclear stations will be built as base load plants and, where appropriate, coal or oil-fired plants will be designed for lower load factors for a number of years to come. It is likely, however, that by 1990 a very large fraction of total energy growth will be supplied from nuclear power plants, probably operating in conjunction with pumped storage and conventional hydro plants designed to meet peak load conditions.

In Manitoba Nelson River hydro power appears competitive with fossil fuel power plants on the basis of fuels cost of 40¢ per million Btu. In view of the fact that fuel costs are likely to exceed 40¢ by 1980, the Nelson River development will remain competitive and will make an important contribution to electrical generation in this region. In Alberta and to a lesser extent in Saskatchewan a significant share of power generation is based on natural gas. However, in view of the expected increase in natural gas prices and the availability of low cost coal, it is very likely that coal will continue to play a very substantial role in future power generation in these two provinces and it is unlikely that nuclear power will penetrate the Alberta or Saskatchewan markets in the next 25 years. Gas pricing policies of the future, in Alberta and also the rest of Canada, may purposely discourage the use of this premium clean fuel for power generation purposes.

In British Columbia, hydro power on the average is still cheaper than power from fossil fuels and will continue to play an important role in the electrical generation in that province. Environmental considerations, however, could reduce the attractiveness of hydro power in the latter 1980's and 1990's and this increasing amount of the British Columbia load growth will likely be met with nuclear generation and there is the possibility of significant thermal generation based on a large low cost coal deposit.

Future increases in fossil fuel prices may make nuclear generation more attractive. In addition to fuel cost increases the relative capital costs of nuclear and conventional plants may also change in favour of the nuclear alternative. The

COMPARISON BETWEEN TOTAL UNIT ENERGY COSTS (on the basis of 1972 $) OF NUCLEAR POWER AND FOSSIL THERMAL POWER FOR 500 MW IN ONTARIO, FOR VARIOUS FUEL COSTS AND LOAD FACTORS, TAKING INTO ACCOUNT TRANSMISSION COSTS TO NEAREST LOAD CENTER AND RESERVES, IN 1972.

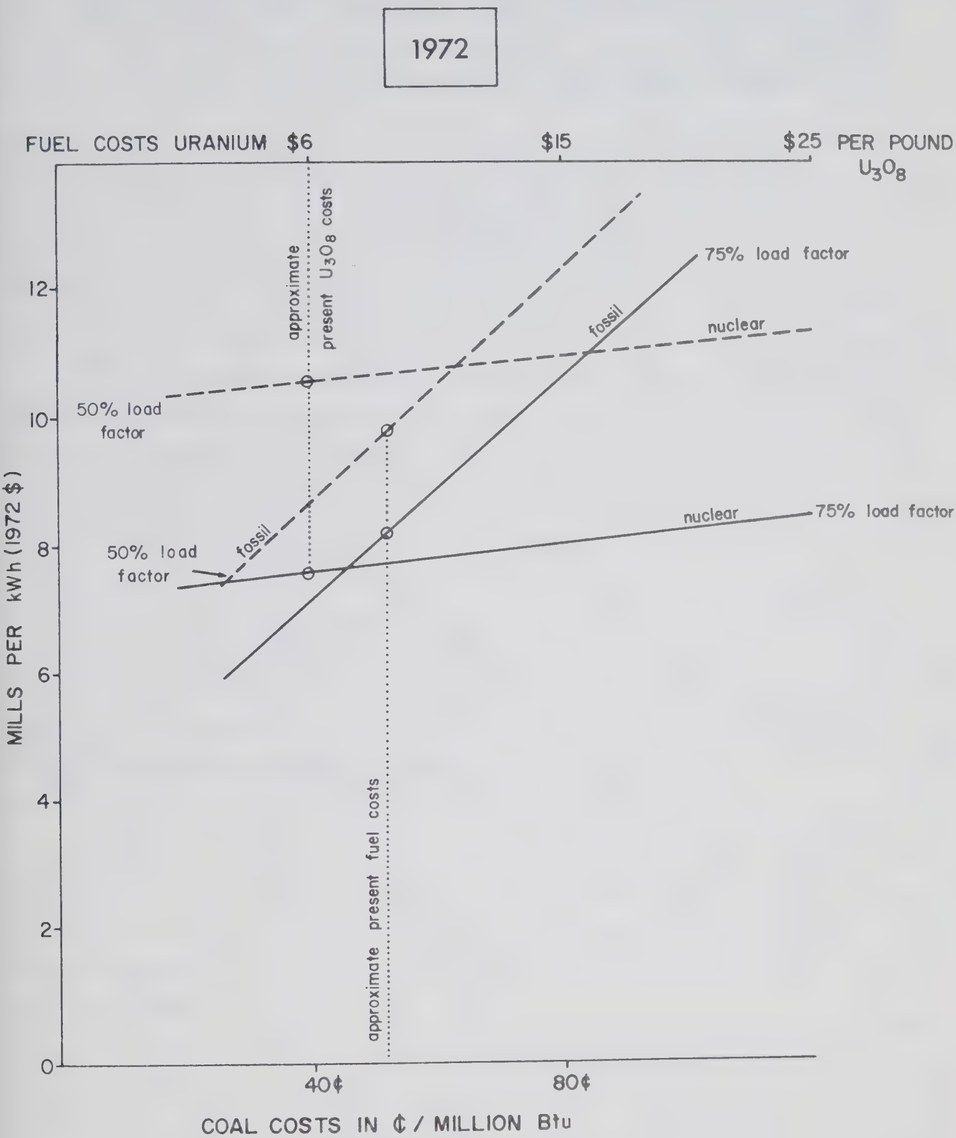


Figure 1

ESTIMATED TOTAL UNIT ENERGY COSTS (1972 $) OF NUCLEAR POWER AND FOSSIL THERMAL POWER FOR LARGE POWER PLANTS IN ONTARIO, FOR VARIOUS FUEL COSTS AND LOAD FACTORS, TAKING INTO ACCOUNT TRANSMISSION COSTS TO NEAREST LOAD CENTER AND RESERVES, IN 1990.
(ESTIMATES FOR NUCLEAR COULD VARY PLUS OR MINUS 20%, FOR FOSSIL PLUS OR MINUS 10%)

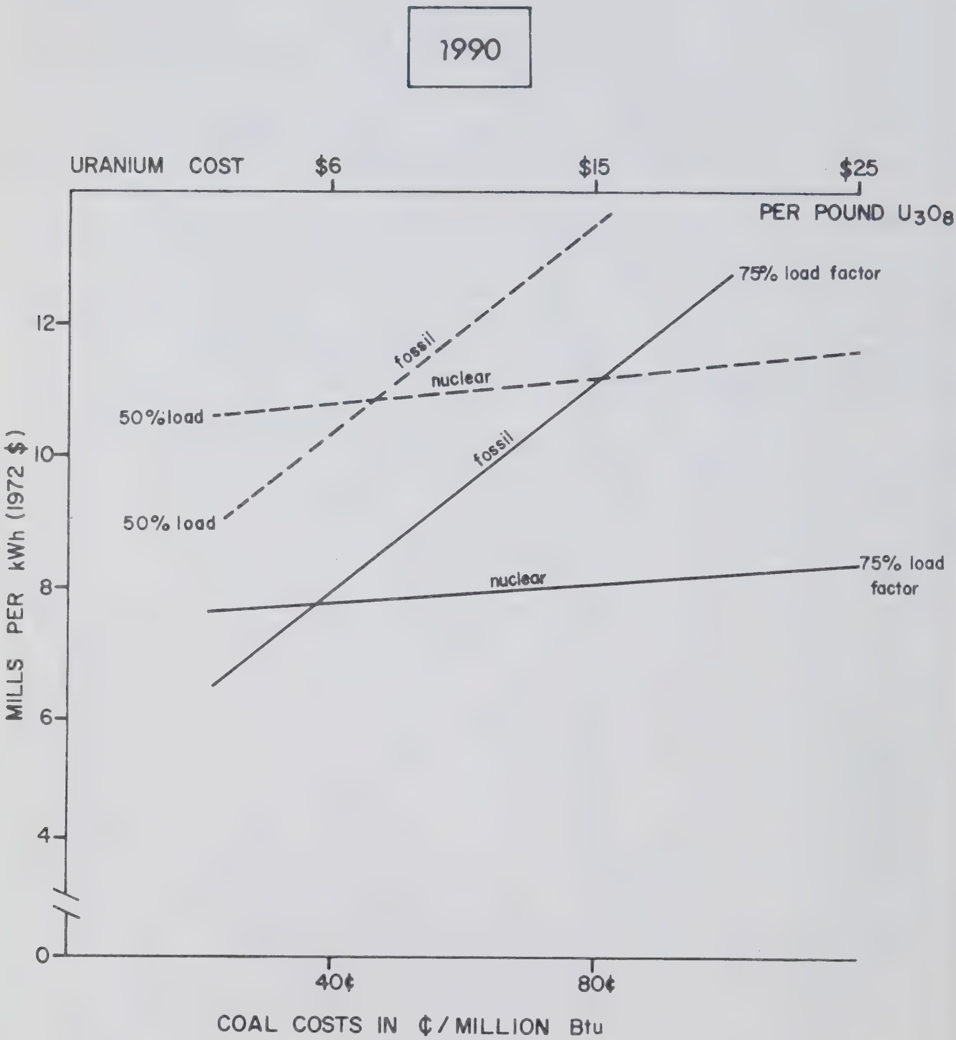


Figure 2

capital cost of building fossil fuel plants will probably be influenced more by environmental considerations. There is also a greater opportunity for capital cost reduction in nuclear plants since the technology is still comparatively new and cost improvement is likely to result from additional research and development and from the economies of scale which are still available.

Figures 1 and 2 compare the relative economics of nuclear and conventional thermal-electric plants on the basis of varying fuel and load factor conditions.

Competition Between Oil and Natural Gas

Western Canadian natural gas is currently sold in markets stretching from Vancouver to Montreal. With the possible exception of Montreal, natural gas is undervalued in most market areas when compared to other fuel prices. The current low prices of natural gas in Canada are a result of several factors. Western Canadian producers of natural gas in the 1950's were willing to accept low prices at the wellhead in order to facilitate the construction of large diameter pipelines to carry their gas to consuming centres. The two major gas pipelines were partially predicated on exports to the United States at a time when U.S. prices for natural gas were relatively low, primarily because of wellhead price control by the Federal Power Commission in Washington. Consequently, in order for Canadian gas to penetrate United States markets it had to be priced against U.S. competition and Canadian wellhead prices reflected low natural gas values in the United States. Another contributory factor was the lack of competition between gas purchasers in the field.

To finance the construction of transmission lines producers were obliged to sign long-term gas sales contracts with minimal price escalation clauses and redetermination provisions. As a result gas prices in Canada throughout the 1960's remained fairly constant. In most market areas where natural gas was available it captured a very high percentage of new market growth and accounted for wide-scale conversions in the existing market from coal and oil.

During the 1960's oil prices were also fairly stable. This was generally true both for domestic crude and products and international supplies. While gas was in a favoured position, market developments were fairly orderly during the decade.

Over the last three years international petroleum developments and supply-demand considerations in the United States have substantially changed the inter-fuel relationship that existed in the 1960's.

To illustrate the effect that changing prices have on the relative demand growth for oil and natural gas the current and future industrial market for oil and natural gas in the Toronto/Hamilton area has been analysed. Figures 3 and 4 illustrate the costs of oil and gas to small and large industrial consumers in the Toronto/Hamilton area. Small industrial plants, using No. 2 fuel oil, are situated on the left-hand side of the curve, and the largest industrial consumers, burning No. 6 fuel oil, are at the right side of the curve. The purchase price of oil and natural gas is shown in cents per million Btu and is the delivered cost of each fuel to the plant. These costs do not include additional costs incurred for fuel utilization.

FUEL OIL AND NATURAL GAS PRICES IN THE TORONTO-HAMILTON AREA IN 1969 FOR INDUSTRIAL USERS

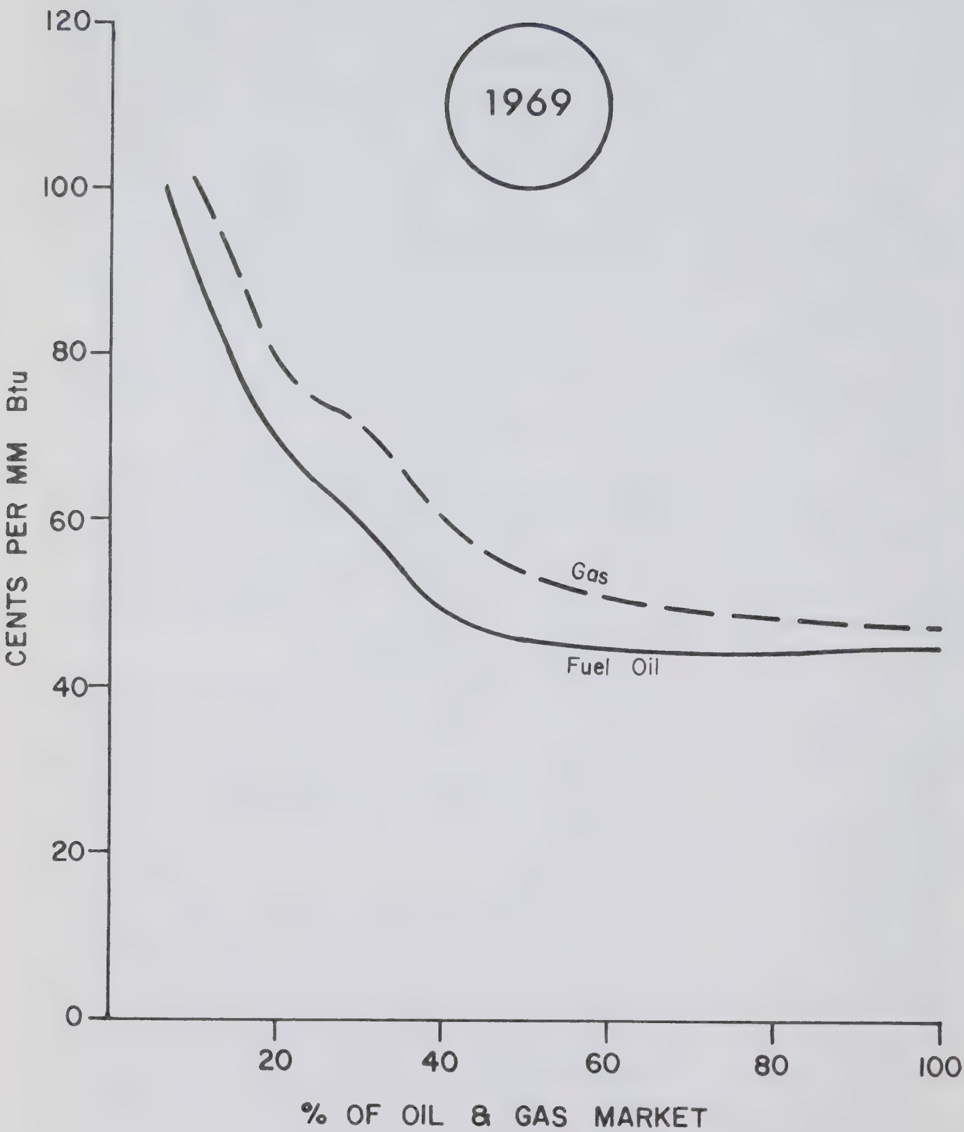


Figure 3

FUEL OIL AND NATURAL GAS PRICES IN THE TORONTO-HAMILTON AREA IN 1972 FOR INDUSTRIAL USERS

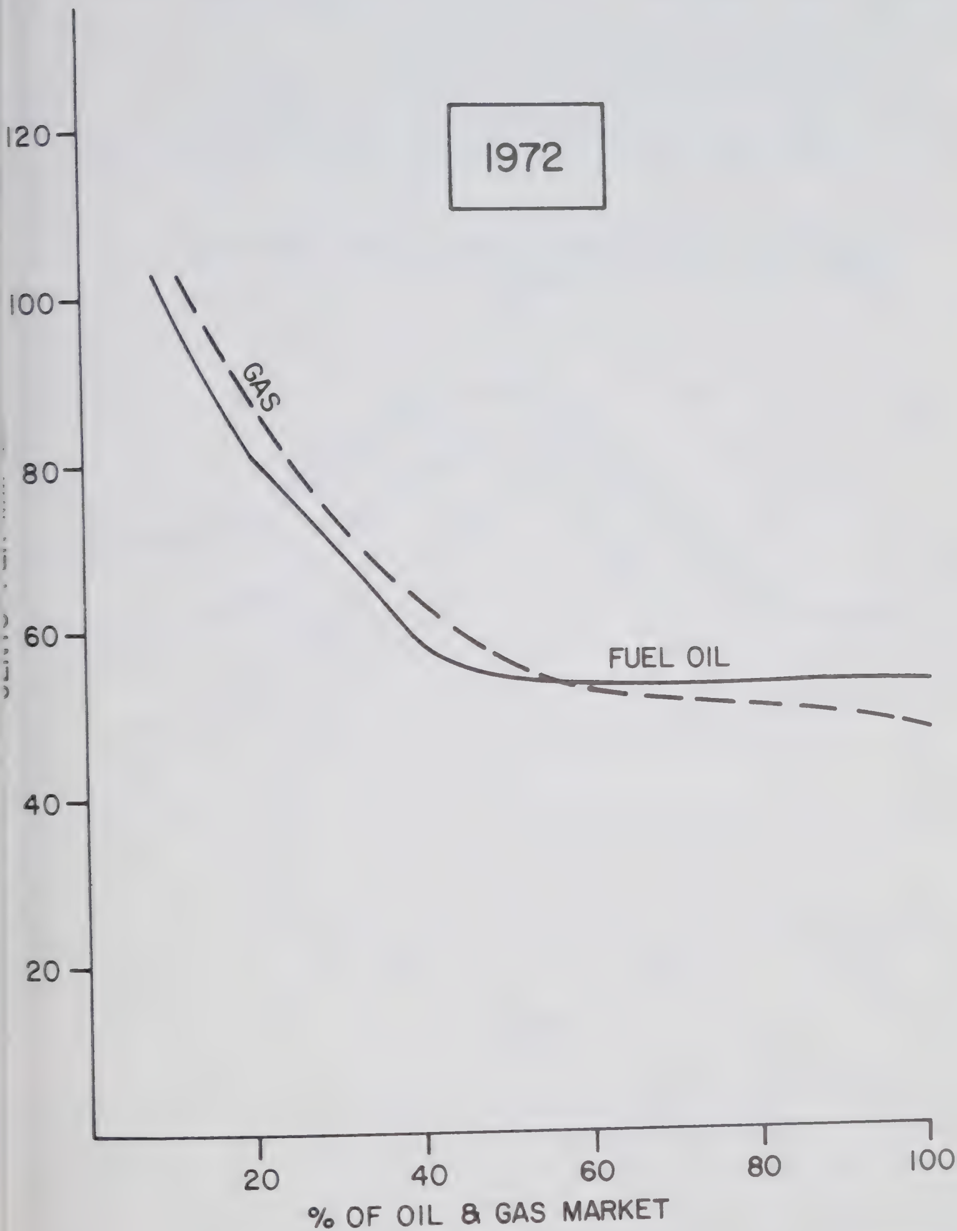


Figure 4

In 1969 gas sold at a premium over oil products ranging from 2 to 6¢ per million Btu for large industrial consumers and from 10 to 15¢ per million Btu for medium and small consumers. As stated earlier, under these relative price conditions, natural gas was capturing a very large percentage of new market growth.

From the late 1960's to 1972, gas prices did not change significantly to industrial customers in the area, but petroleum product prices increased significantly. Currently, natural gas is even a better bargain for industrial customers in this area than it was in the more stable period of the 1960's.

Figures 3 and 4 also illustrate the portion of the industrial market that is most sensitive to relative price changes. About 40 customers account for 50 or 60 per cent of the total industrial oil and gas consumption in the Toronto/Hamilton area.

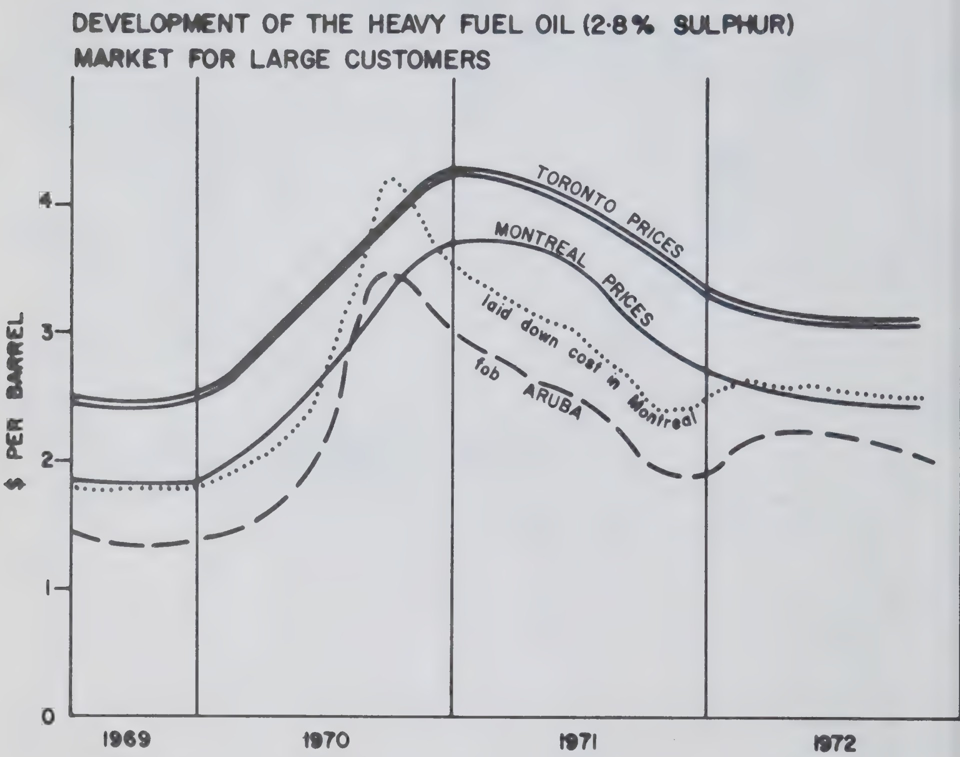


Figure 5

Under the National Oil Policy heavy fuel oil can be imported into Ontario. The price of heavy fuel oil in Toronto is determined by international market mechanisms and reflects fuel oil values in the Caribbean plus appropriate transportation charges. An historical time series of Toronto fuel oil values (Figure 5) shows a close correlation with fuel oil values in the Caribbean, Western Europe, and the east coast of the United States. For a large portion of the industrial market (that

market consuming heavy fuel oil) fuel oil, with prices determined internationally, is competing with natural gas at a price which is influenced by North American factors.

Natural gas has not been priced to take advantage of increased costs of heavy fuel oil. An analysis shows that gas prices could immediately increase at least 10¢ per million Btu in the industrial market and still return to its relative position in 1969 when gas was growing rapidly. If fuel oil prices remained the same and gas prices were increased to industrial consumers by 15 or 20¢ it would mean that a significant portion of the large industrial market would shift to fuel oil. This case, however, is not considered realistic. As outlined earlier, crude oil prices are expected to increase substantially in the coming years. Reflecting these crude oil price increases it is expected that residual fuel oil will increase in price from about $3.00 per barrel in Toronto for large consumers in 1972 to close to $5.00 (1972 dollars) per barrel in 1980. This increase will not only reflect crude oil price increases internationally, but will also take into account probable environmental regulations which could call for 1 per cent sulphur fuel oil in the Toronto area by 1980.

As fuel oil prices increase the competitive price for natural gas would also increase. Figure 6 indicates the total projected industrial market demand for oil and natural gas in the Toronto/Hamilton area. The solid line at the top of the graph represents the market growth forecast and the dashed line represents the portion of the market that natural gas could capture under various pricing conditions. The starting point for these dashed curves is 1972 when gas made up approximately 65 per cent of the combined industrial consumption of oil and gas.

The interpretation of the graph is as follows: if gas prices bear the same relationship to heavy fuel oil prices in the future as they did in 1972, and if fuel oil prices rise to about $5.00 per barrel by 1980, gas prices to large industrial consumers can rise to 80¢ per million Btu in 1980 and still increase substantially the share that natural gas has of the total industrial market in the Toronto/Hamilton area. If the relationship between gas and heavy fuel oil prices to large users returned immediately to the 1969 differentials (i.e. an increase of 10¢ for gas) then gas could be priced at 90¢ in 1980 and still capture an almost similar portion of the market that it had under the 80¢ case.

If the differential was pushed 5¢ per million Btu beyond the 1969 differential, (i.e. 95¢ per million Btu in 1980) many industries would be considering a shift to fuel oil and it would be difficult to say precisely the share of the market that gas would command. At higher price differentials gas would immediately lose a significant portion of the large industrial consumers and then recover by expanding sales and growth in the smaller and medium sized industrial market thereafter.

This analysis applies only to the Toronto/Hamilton area. The competition between natural gas and fuel oil is quite different in northern Ontario or Montreal.

In this analysis only the industrial market was analysed. No precise adjustments were made for load balancing considerations through the sale of interruptible or off-peak gas. To determine competition or appropriate city gate prices for natural gas, domestic and commercial markets would have to be taken into account, along with changing distribution economics. Analysis of gas prices to domestic and commercial customers in the Toronto/Hamilton area, as compared to No. 2 fuel oil costs, shows that gas is significantly under-valued in these markets.

GAS SALES IN THE TORONTO-HAMILTON AREA FOR VARIOUS ASSUMPTIONS ABOUT GAS PRICES IN 1980 FOR LARGE INDUSTRIAL USERS

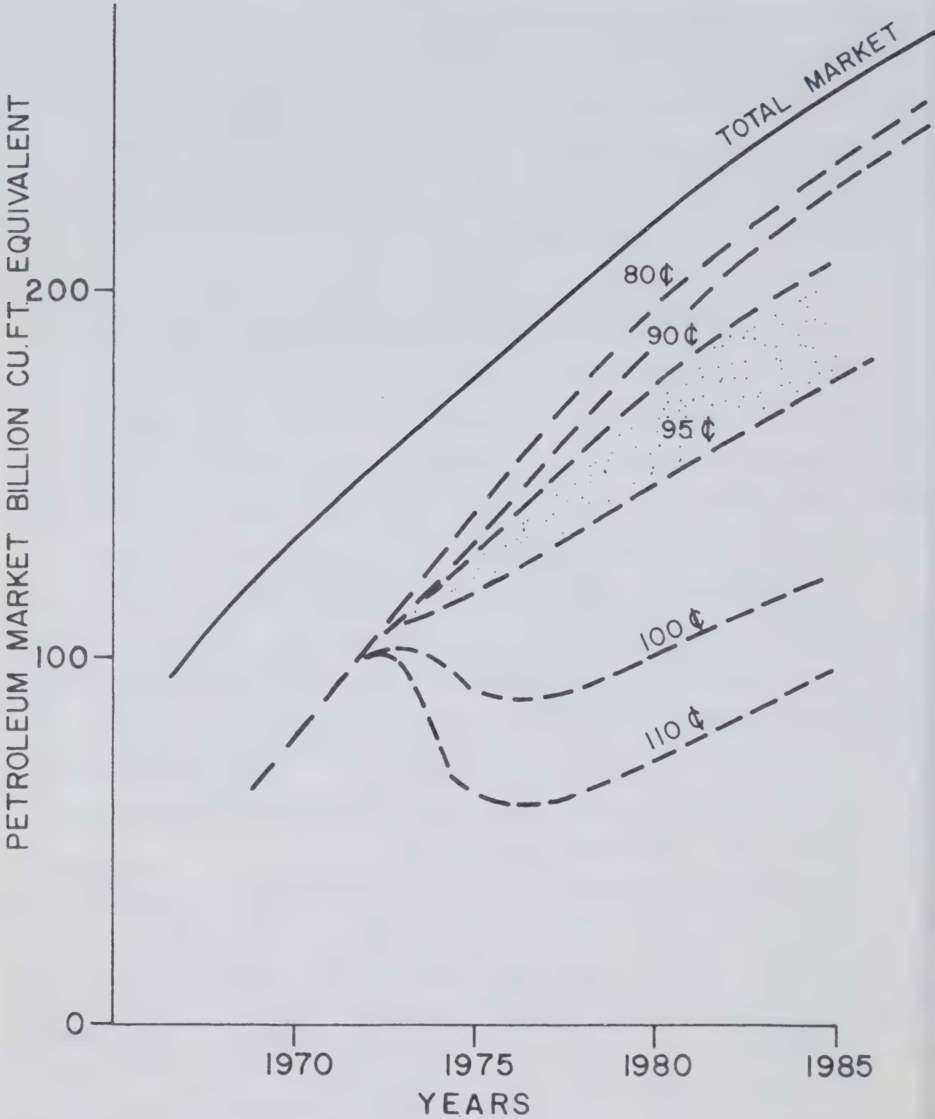


Figure 6

When comparing oil and gas prices it is not sufficient to compare the cost per Btu delivered to the consumer. Costs of fuel utilization must also be taken into account in order to determine the most economic fuel decision for any consumer. However, as the cost of burning gas is considerably less than that of using fuel oil or coal, gas prices would appear to be even more under-valued. Premium values for the domestic market could range from 20-30¢ per million Btu for gas to equate it with No. 2 fuel oil. Premium values for commercial and small industrial customers could be between 5-20¢ per million Btu. For very large industrial customers the premium value shrinks to somewhere between 2-6¢ per million Btu. Industrial customers which utilize fuel for its form value in special applications can justify a wide range in premiums.

In conclusion, changes in relative fuel prices can have a significant effect on future demand patterns. Given the current inflexibility in gas pricing, and a rising price for petroleum products, the relative difference between oil and gas prices will continue to increase. For gas prices and wellhead values to reflect changing competitive market forces a more flexible system of gas pricing is required. Large volume sales of gas in Western Europe and elsewhere in the world have recently been made where future contract prices have been related to competitive fuel prices and other economic factors. Recent moves in Canada towards the establishment of more frequent redetermination periods for gas contracts indicate a development in the same direction.

Chapter 7

SECURITY OF ENERGY SUPPLY

Canada is self-sufficient in terms of energy production but there still is the problem of security of supply. Imported coal from the United States provides the fuel for 36 per cent of the total electrical energy generated in Ontario. All the markets east of the Ottawa Valley rely on imported crude oil. These problems have been generated by the distance of the principal sources of Canadian fuel far from major areas of consumption. The cost of transportation of these fuels has played an important role in the development of export and import policies.

Electrical generation in Ontario and the Maritimes could be affected by a disruption of the primary source of fuel for their thermal power stations. Ontario could achieve security of supply by using western Canadian coal at a higher price and by greater dependency on nuclear power stations in the future. Stronger electrical interconnections between provinces, especially with Quebec, and reliance on nuclear power, may provide the answer for the Maritimes.

Uranium supply for nuclear power stations is no problem in Canada. Eighty per cent of the total material and equipment required for a nuclear generating station is available from Canadian sources. The necessary heavy water plants are also in Canada but more will have to be built to keep up with any increase in the number of nuclear plants.

World oil operations have changed so that traditional patterns of oil supply no longer are the same. The Middle East will be the focus of attention as a restriction by one of the major suppliers or renewed outbreak of hostilities between the Arab countries and Israel would have a worldwide effect on the supply picture. To counter a possible restriction of supply to Eastern Canada many solutions have been suggested. These include extending the western pipeline to Montreal, refineries holding more than the 40 days stock they now hold, and establishment of government stockpiles.

The long-term solution to the Canadian oil security question could be partially solved if oil were found off Canada's east coast or in the eastern Arctic.

Canada is one of the few nations of the world having an industrial base and yet being self-sufficient in terms of energy production. However, our principal sources of fuel are located in areas remote from our major areas of consumption, and accordingly the costs of transporting fuel have played an important role in the development of our export and import policies. These policies have resulted in the establishment of viable energy industries in Canada, but still leave areas of Canada dependent on supplies of imported fuels. This reliance on supply which could be affected by events or circumstances beyond our control required the federal government to make difficult choices between the use of domestic sources at higher cost to Canadian consumers or reliance on foreign supplies, which carried with it the acceptance of possible fuel shortages. This chapter deals with this "Security of Supply" dilemma.

Electrical Energy

About 75 per cent of Canada's electrical energy is produced by domestic hydroelectric sources which naturally pose no security of supply problems. However, if the other 25 per cent of the energy generated in Canada, from both conventional and nuclear thermal-electric generating stations is examined, it is found that more than half of this energy is produced from fuels coming from foreign sources. In 1971, for example, 29 billion kWh of a total of 51 billion kWh of energy generated by Canadian utilities from fuel-fired plants was produced through the consumption of imported fuels. It might also be observed that although the generating equipment required to meet domestic needs is located in Canada, a substantial portion, especially in conventional thermal generating stations, is supplied by foreign manufacturers.

Regional dependence on foreign sources of fuel is even more marked. In Ontario, in 1971, over 82 per cent of all fuel-generated energy, and over 36 per cent of all electrical energy generated in the province, was produced from coal imported from the United States. In the Atlantic Provinces, 34 per cent of electrical energy generated in 1971 came from imported fuel, in this case, imported oil. All other regions of Canada are currently self-sufficient on the basis of hydroelectric resources and/or on fuels available from Canadian sources.

Future trends in electric power generation in Ontario will somewhat reduce that province's dependence on imported coal in percentage terms although there may be an increase in actual volume of United States coal used. This change will result from the increasing contribution of nuclear generation and from some contribution by imported oil which has not, to date, been significant as a source of electrical generation in Ontario. Increased reliance on imported oil will not of course reduce the overall security of supply problem, but rather would increase the degree of risk of fuel curtailment.

The Maritime Provinces are likely to develop increased dependence on foreign oil until nuclear plants can be incorporated economically into the regional power systems. If such nuclear plants were to be constructed strictly on the basis of interconnected Maritime power loads, this situation would not develop until the mid-1980's at the earliest. The advent of nuclear energy in this area however, could be accelerated through the construction of a nuclear plant designed to meet a combination of Maritime and export loads.

During the next two or three decades, British Columbia, Quebec and Manitoba will remain heavily dependent on hydroelectric resources. Alberta and Saskatchewan will continue to rely heavily on domestic coal and oil.

No problems are presently envisaged which would result in the curtailment of the necessary supplies of U.S. coal to Ontario Hydro; however, the cost of this fuel is expected to continue to rise and problems of quality may develop, particularly with respect to sulphur content. If dependence on imported coal supplies were considered unacceptable, Canadian coal could be supplied to the generating plants of Ontario Hydro. Studies that have been carried out on this possibility indicate that there would be a significant economic penalty involved and that there would have to be an upgrading of rail transport facilities between the western coal fields and Thunder Bay.

The increasing cost of imported coal is narrowing this gap, however, and it is conceivable that lower rank western coals will become competitive. Using this lower quality coal would reduce the generating capacity of the existing power plants however and the cost of this loss would have to be evaluated. Another alternative would be to equip the existing or future coal-fired generating plants with dual firing facilities so that they could also burn either residual or crude oil from western Canadian or imported sources. This alternative would carry an economic penalty. It should also be recognized that a situation that would result in a curtailment of exports of coal from the United States would probably also involve an international oil supply crisis, making it highly unlikely that Canada could find additional supplies of foreign oil to substitute for the coal.

In the case of the Maritime Provinces, the cost of returning to the use of local coal supplies in the thermal-electric plants would be prohibitive and it is not practicable to re-open or expand deep-mined coal production in a short period to meet an emergency. If oil and/or gas is found in the offshore regions, alternatives would become available, but this cannot at present be considered assured. Strengthened electrical interconnections with neighbouring utilities, particularly with Hydro Quebec, could improve security of power supply and could reduce dependence on imported oil in two ways. First, since Quebec is regionally self-sufficient, purchases of electrical energy in an emergency might be available. Secondly, interconnections might allow larger generating units to be employed in the Maritimes thereby hastening the time when nuclear units with Canadian fuel sources could be employed.

In Newfoundland the most likely opportunity for improved security from interruption of imported oil would be to provide an underwater connection to Labrador, but a study has shown that this would be a very costly undertaking. Commercial discoveries of oil in the offshore areas or the eastern Arctic would, of course, provide a secure source of fuel.

While electrical interconnections between regions of Canada have been mentioned as a possible method of improving security, reference should also be made of the interconnections existing or planned with the United States. These exist in New Brunswick, Ontario, Manitoba and British Columbia. One of the benefits of these interconnections is the substantial improvements they provide in security against equipment failures in the Canadian power systems. This security is only slightly offset by the matching obligation for the Canadian systems to provide emergency support for the U.S. utilities in the particular interconnection.

In summary, it can be said that only in two regions, Ontario and the Maritimes, are there risks to electrical energy supply from dependence on foreign sources of fuel. The solution available for Ontario would involve, at extra cost, provision of coal or oil from Western Canada, coupled with maximum rate of development of nuclear fueled plants. Reinforced electrical interconnections between Ontario and Quebec could also assist in reducing this exposure. In the case of the Maritimes, the most economic solution to their long-term security problems would seem to lie in the development of nuclear fueled plants. The time at which this would be an economic course of action could be accelerated either by strengthened interconnections with the Hydro Quebec system or through the export of a

portion of the output of such nuclear plants. In the short term, additional oil stocks appear to be the only solution.

URANIUM AND NUCLEAR POWER

As already noted, Canada has large uranium resources. It is estimated that about 400,000 tons of U_3O_8 can be made available at prices no higher than \$15 a pound with little further exploration. Canada's domestic needs for the envisaged nuclear power program would be about 100,000 tons to the year 2000, while committed exports amount to 60,000 tons. If the price went high enough, say into the range of \$50 to \$100 per pound U_3O_8, it would become feasible to recover immense quantities of uranium present in concentrations of a few tens of parts per million from a variety of relatively common rock types, or perhaps even from the waters of the oceans. Such a price would only increase the cost of power from a CANDU nuclear power station by a few mills per kilowatt hour.

The CANDU nuclear power station used in current Canadian nuclear power plants employs natural uranium. Currently, all aspects of fuel production, from mining to final fabrication are done in Canada with the exception of the manufacture of zirconium alloy tubing used for the fuel sheathing. However, it will be economically feasible to produce the tubes in Canada when production levels increase somewhat. Consequently, within a few years the fuel for the CANDU nuclear power system can be completely of domestic origin.

While not directly related to the question of security of fuel supplies, it is, nevertheless important that the design of the CANDU nuclear power system has been developed in Canada and the engineering is fully carried out domestically. Of the special material and components in the nuclear steam supply system, over 60 per cent is currently supplied from within the country. One third of the value of the imported material comprises the pressure tubes, calandria tubes and boiler tubing all of which could be manufactured in Canada if the market or other circumstances justified it. Another major imported component is part of the control computers. Again, these could be produced entirely within the country, if necessary. The largest single item of imported equipment is the turbine generator. Since smaller size steam turbines have been produced in Canada as well as more sophisticated gas turbines there is no doubt that the country is technically capable of producing the turbine generators required for nuclear power stations. Much of the specialized instrumentation is currently imported but this is due to the small Canadian market rather than to any problems of technical competence or of special materials.

An essential ingredient of the CANDU reactor is heavy water. Although most of the heavy water in the nuclear plants in operation at present has been imported, three heavy water plants are in operation or under construction which should meet the needs of the immediate future. Additional heavy water plants will have to be constructed to meet the demands for the predicted nuclear power program in Canada, thus ensuring a completely domestic supply of this essential ingredient.

For the nuclear plants as a whole, over 80 per cent of the material and equipment is currently being supplied from within the country. With relatively modest investments or modest increases of costs in a few areas, it would be

feasible to become 100 per cent self-sufficient. In the face of the expected high dependence upon nuclear power for the production of electricity in the coming decades this is a situation which could ensure independence from foreign supply and from foreign control over fuel prices as they affect the electrical industry.

METALLURGICAL COAL

As indicated in an earlier chapter of this report, there are abundant supplies of metallurgical coal available in Western Canada. At present, however, it is more economical for the steel mills of Ontario to import metallurgical coal from the United States (7.4 million tons in 1972). A considerable percentage of these imports (52 per cent) comes from mines in the United States which are owned by the Canadian steel mills. Another 27 per cent is covered by long-term contracts.

Our imports of metallurgical coal in 1972 were more than counterbalanced by our exports of 9.4 million tons to Japan and these exports are expected to grow faster than imports. Canada is therefore more than self-sufficient in terms of metallurgical coal production, but economics dictate the use of imports to our major steel mills. Aside entirely from the economic arguments, it would be difficult to switch quickly from U.S. coal to western Canadian coal for metallurgical purposes, because of differences in quality, production capability at the mines and transportation capacity. To do so, would involve abrogation of export commitments for metallurgical coal as well as a crash program to install the necessary transportation facilities.

While Canadian steel mills are not using Canadian metallurgical coals for the present operating processes, they keep close watch on current developments. They appear to be satisfied with the security of supply from United States sources. However, when a curtailment of U.S. supplies appeared possible in 1969-70 there was an immediate approach to the federal government by one steel producer seeking access to Canadian coal production at a time when all production capacity was committed to export contracts.

OIL AND OIL PRODUCTS

Although Canada has been producing more oil than she consumes since 1970, only about one half of her oil requirements are supplied from indigenous sources, the balance being imported and the surplus being exported. In 1972, exports amounted to 951 thousand barrels a day (Mb/d) of crude oil and 193 Mb/d of products while imports were 757 Mb/d of crude oil and 142 Mb/d of refined products. The latter included approximately 20 Mb/d of tanker-borne products for central and western Ontario, i.e. on the western side of the "Ottawa Valley Line".

Virtually all of the markets west of the Ottawa Valley are supplied from indigenous sources. There are less than 15 Mb/d of products (mostly residual fuel oil) imported to our west coast, mainly from California, and somewhat smaller volumes consisting of miscellaneous and specialty products into Ontario from the adjacent United States. These supplies are considered secure. However,

Eastern Canada (the Maritime Provinces, Quebec, Newfoundland and the Ottawa Valley Region of Ontario) is completely dependent on tanker-borne imports from overseas.

It is anticipated that by 1980, Eastern Canada's requirements for crude and products will have increased to more than 1 million barrels per day. Oil requirements in the area are increasing at a faster rate, and account for a higher proportion of total energy supply than in the rest of the country; thus the significance of supply and its security is growing in relative as well as absolute importance.

In the past, the security of Canada's imported petroleum supply was not considered to be a problem in then prevailing conditions of world supply. However, the magnitude and nature of world oil operations are now such that traditional patterns of oil supply no longer have the same relevance;

> In this decade, the Middle East will be the key to the balance in the supply and demand pattern. If the countries in that area which have the largest potential for increasing their output do so to the extent required, then a relatively stable world oil supply situation will pertain for the 1970's. If, however, even one of the very large exporters were to restrict its production for an extended period, a politically and economically unstable world oil situation would result. It is assumed that the impact on Eastern Canada of an interruption of oil supply would be proportionate to the global diminution in the world trade in oil.
>
> A fourth outbreak of major Arab-Israeli hostilities is a possibility which cannot be ignored. The effects on world oil trade of such a development or other developments affecting the oil producing states, cannot be readily determined.
>
> The United States oil industry has reached the stage where it is unable to expand its production significantly, at least in the short run.
>
> The decline in oil discoveries in the traditional oil-producing areas in Canada and the decline in known reserves in these areas, are unlikely to be compensated for, in the short term, by the exploitation of sources in the Mackenzie Delta, the Arctic Islands or areas off the east coast.

In calculating the impact of a supply crisis on Canada, the assumption has been adopted that the impact on Eastern Canada of an overseas supply interruption would be proportionate to the global diminution in the world trade in oil. There are, of course, circumstances in which Canada might be proportionately better off or worse off than other oil importers.

A survey of existing and planned storage capacity and stock levels in Eastern Canada indicates:

(a) average stock levels are arithmetically equivalent to 70 days' requirements, but

(b) allowing for oil not normally available in tank bottoms, the level of coverage is reduced to the equivalent of 58 days' consumption, and

(c) after allowing for seasonality of product requirements and other factors related to the practical difficulties of maintaining supply and distribution during an extended interruption, the coverage is reduced even further, to the equivalent of about 40 days' requirements.

Canada's security of oil supplies might best be assured through reliance on domestic supply. The more immediate domestic capability lies with western Canadian resources. However, these resources are not now connected by pipeline to Eastern Canada and, because supply from that area would be expensive, it is less desirable in the present analysis than the alternatives available.

It might be possible in a crisis to use the existing Trans-Northern product pipeline to move up to 35 Mb/d of crude oil from Toronto to Montreal but this would require a major realignment of product movement by truck and tank car to service the areas now supplied by Trans-Northern.

Since there is a potential for new domestic supplies being developed off the Canadain east coast and in the eastern Arctic by the end of this decade, measures taken to offset the current security risks should be determined with this in mind also.

Methods of increasing our security of supply over this *medium-term period* have been suggested by industry and others and include:

Extension to Eastern Canada of pipeline facilities from Western Canada;

Increased holding of stocks in Eastern Canada through better utilization of existing tankage capacity and construction of additional capacity;

An arrangement whereby the U.S. and Canadian governments would, in an emergency, endeavour to maintain and increase export of oil to each other;

Acceleration of petroleum exploration in Canada's frontier areas accessible to eastern Canadian refineries;

Establishment of a Canadain tanker mercantile marine;

Special governmental arrangements with producing countries in lieu of the normal company-to-company supply arrangements;

Special government-owned stockpiles of petroleum for civilian and for military use in emergencies;

A formal program of petroleum product rationing, to be put into effect when indicated by the conditions of a specific emergency;

Inter-energy substitution. For example, emergency stocks of coal for thermal stations in the Maritimes designed for dual purpose burning of oil or coal, and interconnection of the Quebec and Maritime hydroelectricity systems so that available electricity could be sent from Quebec to the Maritimes in time of emergency.

The government's current concern about supply security would be much greater if Ontario were not being substantially supplied from western Canadian sources. The adoption of the National Oil Policy in 1961 rejected the idea of a pipeline to Montreal and imposed the economic penalty of the more costly Canadian oil on Ontario consumers, but it also permitted Quebec refiners access to cheaper foreign supply and allowed western Canadian crude to attain the market growth which had been so badly needed.

Because imports of foreign oil to Eastern Canada have not yet been subjec to interruption, it can perhaps be argued that supply of western Canadian oil tc Ontario has not provided any actual benefit in terms of avoiding supply inter-

ruption. It should be noted however that imports into Eastern Canada are now less secure because of a lesser percentage contribution by Venezuela to Canada's total imports and therefore a greater reliance on Middle East supplies.

If a pipeline were now constructed to carry western oil to Montreal solely on the grounds of enhanced supply security, the whole of any extra delivered cost would have to be attributed accordingly. Since in current circumstances, western oil production is at or near its potential, Canadian supply transported to Montreal would have to be at the expense of exported quantities and the producers would look for a comparable return from the new market.

Historically, Canadian crude in Ontario has cost about 50 cents a barrel more than foreign crude in Quebec. The corresponding total cost of "supply security insurance" for Quebec may be judged from this difference, bearing in mind that, although past price relationships need not hold, the cost of moving oil from Ontario to Quebec would add an additional cost of about 15 cents a barrel.

As for the "security argument" for such a pipeline, there are other means which seem to offer a better balance of costs against benefits in covering off Eastern Canada's security exposure until such time as indigenous oil can be more economically introduced. These other means include augmenting the current average stock level of crude oil and refined products in Eastern Canada, a national rationing scheme which could be brought into force quickly during an emergency and a possible oil exchange arrangement with the United States.

In this latter connection, Canada has been discussing with the United States the feasibility and the basis for an oil exchange mechanism under which during an emergency, supplies could be delivered to Eastern Canada from imported flows originally destined to the United States and, at the same time, additional oil would be delivered to the United States from Western Canada. This proposed oil exchange mechanism would function on a "best efforts basis".

As previously noted, a survey of storage capacity and stock levels in Eastern Canada indicated that average stock levels are the equivalent of about 40 days' requirements. It may be possible for the oil industry in Eastern Canada to carry higher levels of stocks without construction of new tankage sufficient to meet perhaps another 5 days' requirements. The dynamics of the oil security situation are such, however, that the adequacy of storage must be kept under constant review.

To illustrate the value of an average stock level of 45 days, assuming that the impact on Eastern Canada of an overseas supply interruption would be proportionate to the global diminution in the world trade in oil, a 45-day supply would permit normal levels of consumption in Eastern Canada for a period of 45 days in the event of a 100 per cent reduction of world oil exports; 90 days for a 50 per cent reduction; 180 days for a 25 per cent reduction and so on. The probability of very high percentage reductions is considered extremely small and a 25 per cent reduction is perhaps a reasonable yardstick for analysis purposes. These calculations assume that at any given time the oil industry maintains its stocks of crude oil and refined products in the balance appropriate to anticipated normal refinery runs and seasonal factors.

The possibility of an oil exchange with the U.S. and the potential effect of a national rationing scheme should extend the supply of oil well beyond an assumed "crisis period" lasting some six months.

Longer term solutions to the Canadian oil security question might be afforded by the discovery of oil off Canada's eastern offshore or in the eastern Arctic at locations which could serve eastern Canadian markets.

The question of reducing exports during times of emergency has been noted previously in connection with metallurgical coal. As for oil, it is not clear that Canada would benefit significantly from such a step since the transportation capability is not likely to be present to deliver the interrupted exports to those areas in Canada which would be potentially short of supply. On the other hand, a program of *gradual* withdrawal of oil from the export market and construction of the necessary transportation facilities to become increasingly self-sufficient in terms of petroleum and its products, could be instituted, at some significant cost to the Canadian economy.

Continuous assessments of the security question are under way. To date, the security threat has not appeared serious enough to require arrangements to be made to supply the area east of the Ottawa Valley with western Canadian crude oil.

Chapter 8

CANADIAN ENERGY IN AN INTERNATIONAL CONTEXT

Canada is self-sufficient in terms of energy production but plays only a relatively minor role in the supply of energy to the United States although certain regions are dependent on Canadian supplies. In 1972 Canada supplied 6 per cent of the U.S. oil requirements and 4 per cent of its natural gas needs. Only 3.3 per cent of the total Canadian electrical energy was exported south of the border and, over the years, electrical energy exchanges between the two countries have been more or less in balance. An important part of our energy trade is the dependence on U.S. coal for supply to Ontario Hydro generators and Ontario steel plant markets.

If we are to maximise export price opportunities for oil and gas and still protect against similar increases in Canada some form of price control mechanism may be necessary. This has implications for the Ottawa Valley line—for price relationships on either side of that line—and for such related issues as security of oil supply in Eastern Canada.

The role of the Canadian energy resource base in the world is very minor and is likely to remain so. Even if oil prices increase to $5 or $6 level, which would accelerate Athabasca oil sands development, it is unlikely that Canada would be making a major contribution to the oil demands of other nations.

CANADA—UNITED STATES

Canadian energy developments are so closely related to energy developments in the United States that a clear understanding of the U.S. situation is required in order to place the Canadian energy situation in perspective.

In the past two years the U.S. "energy crisis" has been the subject of much discussion throughout the world. The discussion in Canada has, perhaps, been such as to suggest that Canada also has an energy crisis. This is not true; although it is true that the impacts of U.S. energy problems have been, and will continue to be felt in Canada.

The U.S. energy crisis did not arrive without giving numerous clear signals of its approach. Oil and gas reserves (excluding the Alaska North Slope) had been declining. Exploration activity in the United States has declined for the past 15 years. Almost all available hydro-power sites of economic significance had been built for a number of years. Nuclear power programs were being delayed. And while all this was happening the demand for energy was increasing at an accelerated rate.

Observing these signals, a number of energy reports had forecast increasing U.S. energy imports, particularly in the late 1970's. However, some industry and government sources believed there was sufficient time to solve these problems and no shortages would develop. Even those who foresaw increasing imports were unprepared for the swiftness and severity of events, particularly those related to

environmental factors. For instance, air pollution regulations have had a substantial negative impact on both the production and the consumption of coal. Low sulphur fuel oil specifications on the east coast and elsewhere have increased the cost of imported fuel oil greatly. Automobile exhaust control devices will increase the use of gasoline substantially. Offshore drilling, open-pit mining, and many other energy activities have been curtailed or prohibited due to environmental concerns. The siting, construction, and operation of conventional thermal and nuclear power plants has been delayed because of environmental and safety considerations. The petroleum industry has been unable to move the crude oil and natural gas reserves of the Alaska North Slope to market due, in part, to the effective opposition mounted by the environmentalists. Offshore lands believed to be highly prospective for oil and gas have been withheld from the petroleum industry because of environmental concerns relating to oil spills.

Even without the impact of environmental concerns the United States would still be faced with the need for increasing energy imports. Environmental factors have increased the amount of required imports and have thereby brought about the crisis somewhat earlier; however, the crisis itself has not been caused by environmental concerns.

The United States is not a country short of energy, or at least, short of energy potential. On the contrary, it has enormous coal reserves and vast reserves of shale oil. In addition, conventional reserves of oil and gas are likely to be found in offshore areas that have not been adequately explored. The current "energy crisis" is the result of a shortage of clean low-cost energy and the time lag that is required to bring higher cost indigenous resources into production without violating current notions of environmental protection and appropriate price. As a result large and increasing amounts of oil will need to be imported in order to supply the United States with sufficient energy until new and/or higher cost indigenous resources can be made available. This outlook poses a security problem of increasing concern to that country.

Current forecasts by industry and government show the United States importing more than half its petroleum requirements in the year 1985. Most of this oil will come from OPEC countries and a very large percentage from the Middle East and Africa. Heavy reliance on these sources is generally considered to be dangerous from a security point of view, undesirable because of the influence this reliance could have on certain aspects of U.S. foreign policy and economically unattractive because of the balance of payments problems it entails. The major thrust of the recently announced U.S. energy policy is to build up indigenous fuel capability as fast as possible, to reduce the security risk and the balance of payments impact. Increased petroleum prices throughout the world and the new licence-fee quota system will help to promote the development of the higher cost energy supplies in the United States.

The new licence-fee system allows for certain basic oil import exemptions which will gradually diminish until they cease in 1980. Canadian oil has been given a basic exemption of 1,240,000 barrels per day of which 960,000 barrels per day are for the area east of the Rocky Mountains and 280,000 barrels per day for the area west of the Rocky Mountains.

The Canadian exemption levels are based on imports achieved during the first three months of 1973 when our exports were the highest on record.

Since Canadian exports of oil, now subject to export control, are expected to increase little if at all in the next few years, the impact on Canada will be gradual as the exempt portion of our exports decreases. If our exports should decline the impact would be even less.

Imports of oil to the United States above the basic 1973 exemption, and a gradually declining exemption in later years will be subject to a licence fee. This fee will commence on May 1, 1973 and reach its maximum level in 1975. The maximum levels for crude oil will be 21 cents per barrel and 63 cents per barrel for all refined petroleum products. The fee schedule applies to all imports above the exempt level. There is no preferential status for any country.

Canadians generally seem to have a very vague understanding of the degree to which Canada can hold itself aloof from international developments that could restrict oil availability to the United States. On the other hand, there is also a lack of understanding of the various control mechanisms which are available to prevent the U.S. energy crisis from resulting in shortages of energy in Canada.

Canadians also seem to have an exaggerated view of the contribution that Canada is making and can make toward solving the U.S. energy crisis. It is often suggested that Canada's bargaining position is enormous because the U.S. need for secure energy supplies is so great. Table 1 shows current and future U.S. oil demand and the possible Canadian contribution to satisfying this demand. In 1965 less than 3 per cent of the U.S. oil requirements were met by imports from Canada and only 6 per cent by 1972. Assuming the full range of possible U.S. imports from Canada to the end of the century, Canada could provide somewhere between zero and 12 per cent of U.S. oil demand.

TABLE 1

U.S. PETROLEUM DEMAND AND IMPORTS FROM CANADA

(millions of barrels per day)

	1965	1972 (est)	1980	1985	2000
U S. Demand	11.5	16.1	20.9	25.0	35.6
Total U.S. Imports	2.5	4.6	9.2	13.8	25.1
Imports from Canada	0.3	1.0	0–1.8	0–2.5	0–4.5
Imports from Canada as a % of Total Imports	12.0	21.8	0–20	0–18	0–18
Imports from Canada as % of Total U.S. Demand	2.6	6.2	0–8.6	0–10.0	0–12.6

Similarly, Table 2 shows estimates of U.S. natural gas demand over the same period and illustrates the magnitude of possible natural gas exports from Canada to that country. Currently gas exports to the United States make up less than 5 per cent of its requirements. Over the next three decades exports could range between 0 and 12 per cent. The minimum import figures shown represent the quantities presently contracted for.

TABLE 2

U.S. NATURAL GAS DEMAND AND IMPORTS FROM CANADA

(trillion cu.ft./year)

	1965	1972 (est)	1980	1985	2000
U.S. Demand	15.6	23.9	26.2	27.5	33.0
Imports from Canada	0.4	1.0	1.0–2.0	0.9–3.0	0–4.0
Imports from Canada as % of Total U.S. Demand	2.6	4.2	3.8–7.6	3.2–10.8	0–12.1

Although Canadian exports of oil and natural gas to the United States are not major factors in meeting total U.S. demand they do have substantial economic importance to certain northern regions in the United States and in particular to mid-continent areas where alternate supply sources are not readily available. Also Canadian exports have security of supply attractions which are important to the United States.

Canadians are also under the impression that Canada exports large amounts of electrical energy to its neighbour. Table 3 indicates that as recently as 1968 there was a net inflow of electrical energy to Canada from the south. More recently our exports have increased as a result of National Energy Board approval of exports of short-term surpluses, but most of the electrical energy crossing the border is made up of exchanges between interconnected utilities. This capacity to exchange energy has benefitted consumers in both countries by providing emergency back-up and reducing costs.

In spite of the recent upward trend of electrical exports there is little chance of such exports supplying even 1 per cent of U.S. needs. On the contrary as our short-term surpluses are all required within Canada by the mid-1980's the export of electrical energy will probably be limited to seasonal and emergency exchanges between utilities unless there develops a specific policy to export energy produced by Canadian nuclear plants built either wholly or partially for export.

At the present time Canada does not export any uranium to the United States for consumption in that country. This is not due to export controls by Canada, but rather as a result of U.S. policy which prohibits the importation of foreign uranium for U.S. consumption. This policy was developed to protect and assist the United States uranium industry and is expected to be moderated or dropped completely as U.S. needs expand rapidly in the late 70's.

A factor often overlooked in discussing Canada—U.S. trade in energy is the fact that we not only export energy but we also import energy from the United States. About 20 million tons of coal and coke are imported annually for thermal power generation and steel making in Eastern Canada. These imports are vital to the Canadian steel industry in maintaining its competitive capability and a very significant part of Ontario's electric power generation is based on imported coal. These coal imports alone were equivalent in Btu value to about 25 per cent of our total oil exports to the United States in 1972. The electrical energy generated in Canada from U.S. coal far exceeds our net electrical energy exports to that country.

TABLE 3

ELECTRICAL ENERGY IMPORTS AND EXPORTS 1967–1972

Millions of kilowatt hours (kWh $\times 10^6$)

Year	1967	1968	1969	1970	1971	1972
Canadian total net generation	165,625	176,378	191,102	204,723	215,101	238,568
Canadian exports to U.S.	3,994	3,988	4,320	5,631	6,881	10,372
Canadian imports from U.S.	4,181	4,451	2,740	3,245	3,253	2,440
Canadian net exports	−187	−463	1,580	2,386	3,628	7,932
Net exports as % of Canadian net generation	−0.11	−0.26	0.83	1.17	1.69	3.32
Net exports as % of U.S. generation	(0.02)	(0.04)	0.11	0.16	0.22	0.46
U.S. generation	1,214,365	1,329,443	1,442,182	1,531,608	1,613,935	1,740,000*

*Estimated.

SOURCE: Statistics Canada.
Electric Power Statistics.

A point for consideration however is the environmental "quality" of our imports and exports of energy to the United States. Canada imports coal with a relatively high sulphur content and exports considerable volumes of the environmentally preferred natural gas—much of which is used in thermal-electric generating stations in the United States.

Up until very recently crude oil production levels in Western Canada were below the maximum potential production rates with producers seeking new or expanded outlets. Early in 1973, however, Canadian crude production reached maximum capability spurred by rapid increases in U.S. demand for Canadian crude. These increased demands resulted from faltering domestic production in the United States, increased demand in that country and failure of certain overseas producers to achieve scheduled increases. In response to this situation Canada moved to control crude exports in order to ensure that Canadian refiners, using Canadian crude, would be supplied with their requirements. This was considered necessary because all Canadian refiners are net purchasers (some major western Canadian producers do not have refineries in Canada) and because some U.S. customers might be prepared to pay more for Canadian crude than some refiners in Canada wished to pay.

These recent events illustrate the U.S. demand pull that some Canadians feel apprehensive about. They ask why should they pay more for their own oil for their own use just because the United States has an energy shortage. Similarly, Canadians living under the National Oil Policy (NOP) umbrella, ask why they should continue to pay more for their petroleum products than they would have to pay for imported products. One of the basic reasons for the NOP was to provide markets for Western Canada production. That production can now find adequate markets in the United States and therefore NOP import restrictions west of the Ottawa Valley line would not seem necessary for that reason. Evaluation of the needs, benefits and appropriateness of the existing NOP would seem desirable for these and other reasons. If Canada could afford to ignore security of oil supply considerations, the overall national interest might be served best by moving towards an open oil economy wherein Canadian prices west of the Ottawa Valley could directly follow international price levels as in Quebec, the Atlantic Provinces, and even the United States which is now more closely linked to international prices through its new import licence-fee quota system.

Should U.S. crude prices increase along with, or even independent of world price increases, Canadian crude prices in Western Canada would probably follow, and product prices throughout Western Canada and Ontario would also increase. If Canadian prices do not increase in line with U.S. prices, then Canada would be exporting to the United States at prices which would not represent full market value. Producing company profits and provincial and federal tax revenues would not be as high as they might otherwise be. It would appear that if Canada wishes to insulate itself against further U.S. crude oil price increases, but still continue to export at U.S. market prices, some control mechanisms must be used to obtain U.S. prices for exports, while maintaining a lower price in the Canadian market. In order to bring international price competition to bear directly on producers and refiner-marketers west of the Ottawa Valley, the NOP import restrictions would have to be removed.

Under the new U.S. import licence-fee quota system the United States is itself moving towards international price parity. If Canadian producers continue to price Western Canada crude in line with U.S. prices, and U.S. policy is to let prices equate to international prices, subject to the import fee differential, then Canada would move automatically towards international parity. In these circumstances it would be U.S. policy that would determine Canadian crude prices. Without a suitable control mechanism this will continue to be the situation.

All of the above questions or options must be considered within the context of our current or changing notions of national security and import dependency.

Natural gas exports to the United States are under the regulatory control of the National Energy Board and, if approval is given for a licence, the decision is subject to approval by the federal government. In 1971 several applications to export natural gas were denied by the National Energy Board, on the basis that reserves then established did not result in an exportable surplus remaining after due allowance had been made for the reasonably foreseeable requirements for use in Canada, having regard to the trends in the discovery of gas in Canada. As indicated by Chapters 4 and 5, if Canada's natural gas potential develops as presently estimated, there could be reserves developed which would be surplus to Canada's needs and therefore available for possible export.

In the past, export licences were granted for periods of 20 and 25 years. The most recent export permits issued in 1970 included licences of a shorter, 15-year, duration. In the future, it would seem feasible to sell any further volumes deemed surplus to Canadian needs on the basis of shorter term licences or with a mix of licence terms so as to ensure that Canada could, if it so wished, curtail its resource development and rely more heavily on its then developed reserves, or, alternatively, increase the proportion of production dedicated to meeting Canadian requirements.

Currently, about half of Canadian natural gas production is being exported. At the time each export licence was granted the border prices were found to be reasonable in relation to the public interest, i.e. they reflected the economic value of the gas in the market place. However, as a result of the U.S. shortage, Canadian export prices have recently begun to fall short of this goal. There are natural gas shortages occurring throughout the United States; industrial customers are being curtailed temporarily and generally speaking, the demand for gas, at the present federal government controlled price levels, cannot be satisfied by available supplies. As a consequence, U.S. pipeline companies and distributors are making large capital commitments for the construction of plants to make synthetic natural gas from liquid hydrocarbons, are importing liquefied natural gas, and are attempting to develop pipeline gas by gasification of coal. The incremental costs for these new sources of gas are at a very high level. These synthetic sources will likely produce gas ranging in price from $1.00 to $1.50 per million Btu. Some of these plants are being constructed in areas now being served by Canadian natural gas. The U.S. Government will continue to control the price of "vintage" gas for the duration of existing contracts. New gas supplies will be allowed to enter the market at substantially higher prices and, as a result, the average price in the United States will continue to increase, although much less rapidly than if all controls were removed.

The adjustment of Canadian export prices for natural gas is complicated by the long-term nature of the international contracts. These contracts by and large contain price adjustment clauses related to the cost of service (including the purchase cost of gas) but are not yet fully responsive to changes in the market conditions in the U.S. The most recent increases in border prices under existing contracts have not been entirely voluntary, but reflect the realities of present federal and provincial policies and the suasion exerted by the National Energy Board. These efforts are also complicated however, by the necessity that the importing companies obtain approval for price increases from the regulatory agencies in the United States. Because natural gas pricing is currently very inflexible in both countries, it will require renegotiation of current export contracts and a flexible system of price redetermination if Canada is to receive full market value for its exports of natural gas to the U.S.

It is interesting to note that significant volumes of natural gas are now being sold in Europe at prices indexed to petroleum product prices. Another possible pricing mechanism is an export tariff combined with federal-provincial agreements under which the collected revenues would be distributed between producing and consuming provinces and perhaps between producers and consumers. An export gas marketing board has also been suggested which would buy all gas for export and negotiate all export sales. Such a board might also need federal-provincial agreements and might sell gas either by direct negotiation or by a system of auction of surplus volumes.

The Canadian dilemma in respect to natural gas is not dissimilar to that of oil. If the United States is willing to pay high prices for Canadian natural gas and if these same high prices are charged in Canada, then Canadian consumers would indeed experience the effects of current and past U.S. gas policies and the current U.S. energy crisis. Again, if Canada wishes to insulate itself from gas price increases, but at the same time receive optimum prices and other terms from natural gas export sales, then it would seem necessary to establish some control mechanism whereby higher prices could be charged on export sales while maintaining lower prices for Canadian markets.

However, one aspect of the natural gas situation is distinctly different from the oil situation. In the case of oil, most of the Canadian production could be sold in the United States and imported crude or products could serve a large segment of the Canadian market, at international price levels. In the case of natural gas, imports are either not available or would be very expensive. Accordingly, Canadian produced natural gas must continue to serve Canadian markets. If the price in these markets is kept lower than opportunity prices in the United States, there will be a significant problem to be resolved with respect to producers and producing provinces.

Canada—The World

The role of the Canadian energy resource base in the world can only be considered for specific resources at a particular price. For instance, the Canadian oil resources are relatively insignificant in the world at prices up to $3.00 per barrel. The Canadian oil sands and the frontier oil resources are more significant at world prices between $3.00—$6.00 per barrel. However, above $6.00 per barrel, the Canadian

resource base is again insignificant because it is likely that oil can be recovered from coal at such prices. In addition, more and more of the world oil shales and oil sands can be processed at such higher prices. Oil shales and oil sands around the world contain more than 100 times the oil stored in the Canadian oil sands and this oil will become gradually available if oil prices increase beyond $6.00 a barrel. Despite the fact that Canada's resource base is fairly large at about $6.00 per barrel, compared to Canadian demand, it is not very significant relative to world requirements in the long run.

Today, Canada plays a relatively insignificant role in the international fuel trade as can be seen from Table 4. Even if oil prices increase to the $5.00 or $6.00 level, it is unlikely that Canada would make a major contribution in satisfying the demand of other nations. However, the Canadian resource base is vital to Canada and could be of strategic value to the U.S. in case of international disturbances.

TABLE 4

WORLD FUEL TRADE IN 1969

	Fuel Trade $ Billion	Per Cent of World Fuel Trade
Canada to U.S.	0.74	5.3
Canada from U.S.	0.26	1.8
Rest of the World to Canada	0.52	3.7
Industrial Nations to Rest of the World	0.83	6.0
Rest of the World to Industrial Nations	11.65	83.2
Total	14.00	100.0

The existence of Canada's sizable petroleum resource base raises the question whether it would be in Canada's interest to associate itself with other resource exporters. However, Canada profits in its oil export trade from the increase in oil prices that is brought about by OPEC countries without entering into any formal relationship and it is probable that this situation will continue.

Canada's imports of crude oil and products are a matter of some security concern, as reviewed elsewhere in this report. Canada's imports of oil from Venezuela have been an important factor in that country's trade accounts. However, Venezuela can expect to find increasing markets in the United States for its oil production, which now seems to be stabilizing. Canadian oil imports from other countries are not such as to be of major importance to any of them.

There might be possible benefits to Canada through a diversification of its oil export markets. At present this is not practical in view of the cost of Canadian crude. The protected U.S. market is the only market in which Canadian oil can compete. In the future there may be opportunities to diversify sales of any crude supplies deemed surplus to Canadian needs, especially if there is a substantial premium paid for security of supply, but the large and high-cost U.S. market would appear to continue to offer the greatest economic return.

Canadian exports of uranium make up 20 per cent of the western world's total at present. Canada, together with Australia, France, South Africa and the United States will likely dominate world uranium trade into the 1980's. Beyond that time Canada's share of the market should continue at a substantial level because of the many geologically promising areas in Canada where uranium is expected to be found.

Canadian exports of coal, now almost exclusively to Japan, are of significance to Canada and are regionally quite important. However, they are not essential to Japan for other than diversity of supply reasons as other major sources of supply exist in Australia and the United States.

In summary, Canada is fortunate to be self-sufficient in terms of energy production capability at a time when other industrialized countries have serious concerns over adequate and secure energy supplies. However, our reserves are such that after meeting our own needs we can only expect to play a relatively minor role in meeting total United States energy requirements and an insignificant role in terms of world requirements.

SECTION III

ENERGY RESOURCES—CHALLENGES AND OPPORTUNITIES

Chapter 1

THE RATE OF RESOURCE DEVELOPMENT

The rate of resource development is driven by many factors—market forces, adequacy of resources, exploitation costs, government policies and corporate strategies. There are many views as to what is an ideal rate for resource development. These are based to a large extent on the feeling of people as to what should happen as far as resource exports from Canada are concerned. Some believe that resources should be developed only for Canadian use while others advocate that energy resources should be traded for the maximum immediate benefit like any other commodity.

Regional growth, Canadian participation and general economic benefits can be either promoted or deterred by the policies promoting a specific rate of resource development. Canadians should consider these and other aspects before choices are made as to the most desirable rate of development. Government policies are designed to shape the course of events towards this desirable rate.

In Section II various production capacity curves for oil and natural gas were displayed. These potential capacity curves were developed assuming free market conditions unhindered by government action. Generally, the curves illustrate what might be expected in the future, if developments were driven by our forecast of international prices without controls on exports. All the curves show production levels for oil and gas that exceed Canadian demand. Although the volumes that are estimated to be surplus to Canadian requirements for oil are different depending upon the resource estimate used, a basic policy question is: How rapidly do we wish to develop resources over and above our own needs for the export market? A further question is: What benefits accrue to Canadians from alternate rates of development?

There is, of course, a close relationship between these two questions as our desire to influence the rate of resource development would depend on the relative benefits of such a change. Clearly, in a "free market" economy, the market forces will determine to a considerable extent the rate of development. An intervention in the market process is only called for if social and economic costs related to the "spontaneous" rate of energy development are not fully recognized in the business decisions. If political objectives make another rate of development desirable then the costs of a change of development rate have to be properly taken into account.

Other chapters of this report assess the economic viability of energy investment patterns in the short-run and analyse the relationship between the collection of economic rent and the rate of development.

The rate of resource development can be defined in many different ways, but for the purpose of this report it will be defined simply as the rate at which production capacity is added to the national capacity.

Three aspects of the rate of resource development will be discussed. Firstly, there is the "expected" rate of resource development. This rate is what could be

expected if free market forces were allowed to operate within the existing framework of government influence. This rate depends to a large degree on developments in geology, technology and economics. This is the rate of development which is generally assumed in the supply/demand analyses in Section II. Secondly, there is the "desired" rate of resource development. This is the end result of a political and economic discussion. This rate could be higher or lower than the expected rate of resource development, depending on economic and political considerations. The analyses in the remaining Sections of this report should yield insights into what the "desired rate" should be. Finally, the success of the government in influencing the pace of development results in the "actual" rate of resource development.

THE "EXPECTED" RATE OF RESOURCE DEVELOPMENT

The expected rate of resource development depends on a large number of factors. The most important are:

The expectations about the *volume of the resources* that can be discovered and developed economically.

The anticipated *success of exploration* in terms of the frequency with which commercial discoveries are made. The success of exploration can change drastically and is, of course, heavily influenced by changes in the geological interpretation and understanding in various regions.

Technical developments that influence the *costs* of exploration, development and transportation of resources. Technological progress has made it possible to explore now in some of Canada's offshore areas and Arctic regions where it was impossible 15 years ago.

Changes in market *prices* for energy commodities are extremely important in the determination of the rate of development.

The availability of *marketing possibilities* in Canada, the United States, or elsewhere, for Canadian petroleum is a necessary condition for any investment in resources.

Changes in *land regulations* and *government take* (i.e. fiscal terms).

Environment considerations, which will vary depending on the area of activity.

Important *changes outside Canada* with regard to new discoveries or changes in taxation development or environmental regulations by foreign governments could also change the rate of resource development in Canada by diverting risk capital.

Changes in the strategies of major oil companies also could have its impact on investments in Canadian resources.

Obviously there are many factors that affect the rate of resource development in Canada, and energy policy should be able to cope with a multitude of possible development patterns. If previously discussed projections of price developments and the Canadian resource base are approximately correct then it would appear that over the next 20 or 30 years Canada could "expect" a rather high rate of resource development.

The "Desirable" Rate of Resource Development

The most desirable rate of energy resource development will be determined in principle in terms of the contribution which can be made to national goals such as regional development, full employment, economic growth, reasonable price stability, a favourable balance of payments, and an equitable distribution of rising incomes.

Briefly, the various economic and political aspects that influence opinion about the desirable rates of resource development are:

> *The overall attitude towards growth.* Those people who do not favour a continuing economic growth—for many reasons—will obviously not favour a high rate of resource development.
>
> *The overall attitude towards the use of Canadian resources.* Broadly speaking one could distinguish two philosophies. The first philosophy is to use Canadian resources as much as possible for Canadian use only and promote consequently an autarkic policy. The main aim of this policy could be to enhance self-reliance and independence and to extend as long as possible the time over which Canadians can use their relatively abundant resource base. The other philosophy is to look at resources as commodities that can be traded in the world market and that Canada should try to obtain the largest possible benefits from the production of her resource base. To a large degree the political attitudes towards the rate of development of Canada's resource base will depend on these two basic philosophies and many political and economic consequences associated with them.

In addition to these two very general political attitudes a large number of more detailed considerations will determine attitudes about the rate of resource development. Some of these are:

> *The overall economic benefits to Canada.* The pace of development will influence the GNP, the balance of payments, employment, etc. All these factors are influenced, to a degree, by the ability of government to obtain the maximum economic benefits during the development and production of the resources. Various economic arguments with regard to these factors will indicate a higher or a slower rate of resource development. Other chapters will deal in more detail with this issue in the short term.
>
> The present *structure of the Canadian economy.* Some Canadians claim that the present structure is oriented too much to resource development in general and that a gradual reorientation towards other economic activities in Canada would be beneficial to the development of the Canadian society. Some of the arguments for this viewpoint are: a higher potential for economic growth, a higher potential for more diversified employment, a higher potential for economic stability, etc. It is obvious that the desirable rate of resource development is directly related to this question.
>
> The degree of *Canadian participation* is an important consideration with regard to a desirable rate of resource development. The development of frontier resources is a highly complex technological process requiring vast amounts of capital. The degree of Canadian participation in the development is directly

influenced by the timing of the development in relation to the ability of the Canadian manufacturing industries and service industries to develop or acquire knowhow, carry out research and development work, and plan the changes and expansions required in their operations. If the rate of resource development is too rapid the degree of Canadian participation might not be optimal. If, on the other hand, the rate of resource development is too slow, Canadian manufacturers might not make the necessary capital investments that are needed so that Canada can benefit from the development of the frontier areas. An optimum degree of Canadian participation depends consequently on an appropriate rate of resource development.

Regional economic considerations: These are of great importance to the overall or regional rates of resource development. For example, the regional economic prospects of the Maritimes, the North, or Alberta, could influence opinions about the desirable pace of development. These are discussed further in Chapter 3 of this Section.

Considerations with regard to the *environment* play a vital role in determining the desirable pace of resource development, especially in the frontier areas where much research is needed to determine the environmental impact resulting from exploration and development activities.

Considerations with regard to *foreign policy and trade*. Canadian/U.S. relations, in particular, could influence attitudes about the desirable rate of resource development. It is obvious that large resource exports will lead toward greater interdependence between the U.S. and Canada, while a slower rate of resource development, combined with increased growth in other activities, might open up possibilities for the export of other commodities which might conceivably have more diversified markets.

Social policies, especially those concerned with a balanced social development of the north, will have their impact on the determination of the desirable rate of resource development.

Canadian attitudes towards *foreign ownership* and *Canadian control* also influence views about the desirable rate of resource development. It is obvious that a high rate of resource development will call for continuing large inflows of foreign debt and equity capital which could affect our domestic control posture.

Considerations with regard to *defence or national security* could have a certain influence on the pace and location of resource activity.

The desirable rate of resource development is subject to a large number of political opinions and economic judgements. The appropriate rate cannot be determined by considerations of energy policy alone. It is equally clear that opinions about the desirable rate of resource development will change over time as economic and political attitudes evolve and conditions change.

The "Actual" Rate of Resource Development

The federal government can influence the rate of resource development, particularly in the frontier areas that are under federal jurisdiction. As mentioned earlier,

rate of development relates to long term considerations and strategies and not to year to year developments. Two important problems are encountered in attempts to achieve an appropriate rate. Firstly, it is difficult to project what the "expected" rate of resource development will be. That is, in the absence of further government action or control only a rough approximation of the rate can be forecast. Secondly, the political and economic discussions about the "desired" rate of resource development will probably only result in a rather broad notion of what the pace of the development should be.

Government viewpoints may be that the rate of resource development is either too high, about right or too low, for the next 10 or 20 years. In the case where the rate is about right, no particular government action, to affect the rate, is necessary. If the rate of resource development is thought to be either too high or too low, the government could moderate or accelerate the pace by utilizing a mix of policy instruments. A short list of these policy options follows:

> The government could either restrict or promote *exports* of oil and gas. A refusal to export important quantities of oil or gas now and in the future will certainly have a drastic impact on exploration activity and development work in the frontier areas. If the rate is considered too low, the government could promote larger long term markets through international negotiation.
>
> The implementation of *foreign investment controls* could reduce investments in frontier development, while the absence of such controls might encourage it.
>
> The government could promote resource development by providing *subsidies or loans* to certain organizations which might undertake high risk developments.
>
> The Canadian government could play an important role in the creation of *research and development* activities that are associated with the petroleum development in our frontier areas. On the other hand, the government could refuse to get involved in such large programs.
>
> The degree to which the government wants to contribute to the creation of an *infrastructure* in the north and the offshore areas will also influence the costs to the industry.
>
> The government could change *income tax* legislation applicable to the petroleum industries. Higher income tax requirements for the petroleum industry will, of course, reduce the incentive to invest. More tax incentives might encourage the petroleum industry.
>
> Requirements of *royalties*, rentals, bonuses or other payments will have an impact on the rate of resource development. The higher such payments, the lower the incentive to explore and produce oil.
>
> The government can participate in joint ventures through *government-owned companies* in the development of Canada's resource base.
>
> Finally, the government can use *moral suasion* to influence the rate of resource development. A clear statement about government policy with regard to the rate of resource development will impact on investment decisions.

It is clear that a large number of these measures will take considerable time to be developed and implemented, while the impact of other measures on the rate of resource development will be hard to determine. Therefore, it is unlikely that the Government can ever hope to fine-tune the rate of development in the short term. However, in the long term, one could attempt to bring the actual rate of resource development close to the general notion of a desired rate of resource development.

Chapter 2

ECONOMIC RENT FROM CANADA'S OIL AND NATURAL GAS RESOURCES

Economic rent is the difference between gross oil and gas selling prices and total production costs, including an allowance for return on investment. Depending on a country's fiscal and other terms, economic rent may accrue to the industry or to the people.

Exploration in the Arctic and in the offshore has been increasing steadily but as yet there is no production and no significant revenues have been collected by the federal government. The question of how much the Canadian government should receive when the production state is reached requires careful appraisal if the people of Canada are to realize the full benefit of resource development in the frontier regions. One of the difficulties in making such an appraisal is that northern areas are still basically unknown, with the cost of exploration and development much more expensive than in the western provinces.

The Canadian system of income tax and royalties is not sufficiently flexible to obtain an equitable share of economic rent under all circumstances. It fails to distinguish between high and low productivity from oil fields and the related cost conditions. Consequently, little initiative is left for the development of small to middle size fields while too much extra revenue may be left with industry in the case of large, highly productive fields.

The benefits of economic rent can be obtained by setting appropriate levels for royalties, taxes and bonus payments or by controlling prices for the benefit of consumers.

If it is determined that the fiscal system used in Canada is no longer adequate, it must be replaced with one which reflects Canadian conditions, not those which may exist in other unrelated parts of the world. While it is possible to benefit from the experience of others, the final product must fit the Canadian scheme.

The cost of developing new oil and gas production in Canada is greater today than ever before. A single well drilled in the Arctic Islands or on the continental margins can cost several millions of dollars compared to an average of several tens of thousands of dollars in the mature producing areas of Western Canada. While the success encountered in exploration has been highly favourable in some areas, petroleum exploration remains a very inexact science at best and, financially, a high-risk activity. The industry can spend many millions of dollars in an area without discovering any economically recoverable hydrocarbons. Thus, in those areas where discoveries are made, the industry must be able, in the long run, to recover expenditures made in futile exploration. The successes must bear the cost of the failures in order for the industry to remain viable. This principle in the industry is known as recovering full-cycle costs (a cycle representing the full economic life cycle of a petroleum deposit from exploration and discovery through

production to abandonment of the field). Any government tax and royalty policy that recognizes the need to maintain a reasonable level of exploration activity must make adequate provision for the recovery of full-cycle costs by the industry.

There are other elements of uncertainty unique to petroleum exploration and production in frontier areas. For example, the environmental impacts and social implications of oil and gas exploration in Canada's frontier areas are difficult to quantify from the point of view of cost. The history of the Trans-Alaska (Alyeska) oil pipeline is ample illustration of this point. In addition, in some of those remote areas now under active exploration in Canada, the technology does not yet exist to produce and transport the oil or gas to market. There is little doubt that the technology will be developed, but at this stage, accurate cost estimation is not possible. Firms that explore on the frontier will evaluate their investments taking into account all of the uncertainties. Such firms will, therefore, require a rather high rate of return on their investment compared to other less risky business ventures. Government land regulations and fiscal terms must recognize the high risk circumstances surrounding the development of new petroleum potential. The private petroleum production industry should be permitted to earn an internal rate of return commensurate with the taking of these risks.

Definition of Economic Rent

Exploration does not generate revenue. Production from oil and gas fields must furnish the industry with sufficient earnings to reimburse non-successful exploration expenditures and cover all the costs of the producing operation including depreciation, field operating expenses, overhead, transportation costs and an adequate return on risk capital. The earnings should also cover environmental costs, which should be "internalized" like other operating costs. Revenues in excess of this amount are defined for the purposes of this report as "economic rent"* and may accrue to either the industry or the owner of the resource, usually the government. Economic rent as quantified herein relates only to oil and gas production and not the total integrated petroleum operation. Nor is economic rent from resources under the jurisdiction of the various provincial governments dealt with in any detail.

The Canadian government is the administrator of resources in the frontier area and, consequently should ensure that a high proportion of the economic rent available from these resources is collected.

Total Amount of Available Rent

With regard to Canada's oil and gas resource base, one could ask the following questions:

What total amount of economic rent is likely to become available from these potential resources?

How efficient is Canada's present rent collection system?

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* Although economic rent can de defined in other ways, the definition used here is the one commonly employed in the petroleum industry today.

How much of the rent is being left in the hands of industry?

The total rent that could be available to Canada depends upon a number of factors:

The total recoverable reserves of oil and gas

Future prices for oil and gas

The total cost of exploration, production and transport of these resources (including an adequate return on capital)

The rate of resource development.

There are at least two ways in which the value of rent can be expressed. Firstly, there is the undiscounted cash value of rent that could be collected from Canada's oil and gas resource base year by year. The magnitude of this total could be in the hundreds of billions of dollars over the next 50 years—depending largely upon the four factors described above.

The second way in which one can express the value of economic rent is by using the "present value" of the rent income stream. A social discount rate of 10 per cent per annum will be used for illustrative purposes. (The present value of the rent, therefore, can be thought of as that lump sum which, if invested now at an annual compound interest rate of 10 per cent per annum, would yield a stream of earnings equivalent to the rent available from oil and gas.) The present value approach is considered to be a reasonable way of assessing like alternatives since royalties or taxes received today by the Canadian government are worth more than the same amount of royalties or taxes received thirty years from now. On this basis $1 received in royalties, for instance, in the year 1980, is worth 54¢ today. The same dollar received in 1990 is worth 20¢ today.

Using the 10 per cent social discount rate therefore, the present value of the available rent over the next 50 years ranges between $10-40 billion depending, once again, upon cost and price levels, the rate of resource development and the actual volume of resources available. Adopting the standard estimate of prices and the larger Geological Survey estimate of resource potential (Estimate I), the value is about $20-30 billion. Of course, if a higher discount factor is used the discounted value decreases and similarly a lower discount factor increases the present value.

It is important to recognize the influence of the rate of resource development on the level of economic rent. Whether a faster or a slower rate of resource development increases the present value of economic rent is largely dependent on the behaviour of future prices. If future prices increase at an average rate which is *greater* than the *discount rate* used to calculate the present value of economic rent, a slow rate of resource development is more beneficial than a rapid rate. That is, it would be worth waiting on the higher prices to develop any but essential resource needs. If on the other hand, prices are expected to increase at a rate *less* than the *discount rate*, a more rapid resource development will increase the present value of the economic rent. Based on the price forecasts

outlined in Section II of this report and a discount rate of 6 per cent or greater, a high rate of resource development will increase the present value of the economic rent. If the estimated resource base is developed at a maximum rate, about $10 billion might be added to the present value of the economic rent. A very slow development, for example one that would be sufficient to supply only Canada's own needs, might diminish the value of the economic rent by about $10 billion under these expressed assumptions. It should be noted here however that there are offsetting forces at work. While the maximum present value of economic rent might well be achieved by a fast rate of resource development, the government policies to achieve a high rate of rent return would tend to reduce the industry activity necessary for fast development. Obviously a fine balance is necessary.

Efficiency of Collection of Economic Rent

The rent collection system for lands under federal jurisdiction is based mainly on income tax and royalty payments with a minor contribution coming from land regulations (lease rentals, etc.). The present royalty system does not differentiate between a company producing oil from wells that average 100 barrels per day and a company that is producing oil from wells that average 5,000 barrels per day. If the former case results in an economically viable operation, then the latter case must necessarily yield windfall profits to the operator, given that similar cost conditions apply in the two cases. The current system is such that on fields of medium size, and average well productivity, the efficiency of rent collection may be relatively high. The efficiency of rent collection in the case of a bonanza discovery, would however, be low. Exactly the same system is applied in every case.

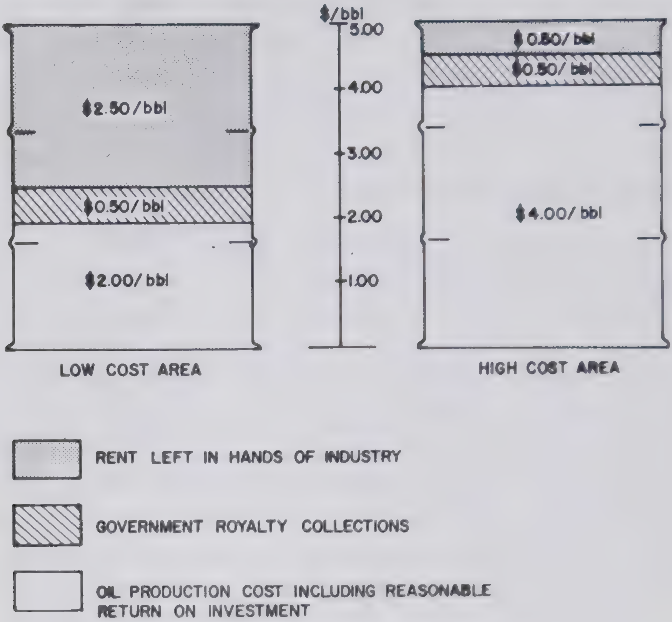
It is interesting to note that with the present federal royalty and tax system, the efficiency of rent collection decreases with higher oil and gas selling prices. On the average, Canada might collect between 50-60 per cent of the rent in the case of intermediate future price levels or between 60-65 per cent if prices were to remain low. If prices were to increase very strongly in the future, then the efficiency would drop to less than 50 per cent.

The diagram below illustrates in a very simplified fashion the concept of rent and rent collection efficiency assuming a 10 per cent royalty. Royalties are calculated on the sales value of the wellhead. For this illustration income taxes have been ignored.

The diagram shows that in a low-cost area where total industry costs plus a fair return on investment are $2.00 per barrel, and the selling price is $5.00 per barrel, economic rent amounts to $3.00 per barrel. With a 10 per cent royalty payment of $0.50 per barrel, the government take amounts to about 17 per cent of the rent available. In the high-cost area, there is only $1.00 per barrel of rent available. Under the same 10 per cent royalty system, the government take would again be $0.50 per barrel but in this case the royalty payment would account for 50 per cent of the available rent.

Income tax payments, which are not shown on the diagram would, of course, increase the amount of rent collected by the government in both cases.

EFFICIENCY OF RENT COLLECTION



Methods of Collecting Economic Rent

There are basically two different approaches by which a nation may realize the benefits of economic rent. Firstly, the rent can be collected by the government in the form of taxes, royalties, and bonus payments, thus increasing government revenues and benefitting the public through various government programs. Secondly, the rent can be passed along in a more direct manner by allowing Canadian industry and Canadian consumers in general the benefit of lower energy prices effected by government controls. Various aspects of both methods will be discussed and it should be remembered that a combination of the two approaches is also a possibility.

Rent Collection by the Government

A discussion of the component parts of the existing federal government's rent collection system follows.

Taxation

Tax policy is only one, albeit a most important factor in the spectrum of overall government influence and should be in harmony with the thrust of other govern-

ment controls and incentives. Existing tax regulations contain special provisions that act as a stimulus to exploration and encourage the expansion of Canadian production capacity. The most important of these provisions can be divided into three categories for corporations whose principal business is in oil and gas.

Capital Cost Allowance. Most fixed capital expenditures (excluding buildings) may be written off at 30 per cent per annum in comparison with the 20% rate applying to most general manufacturing operations.

Exploration Expenses. In general, capital expenditures for geological and geophysical exploration other than investment in fixed assets, may be deducted in total against current income in the year they are incurred, or may be deferred and written off against future income. Development drilling may be handled in the same fashion. This differs from industries such as manufacturing where all capital expenditures are amortized over a period.

Depletion Allowance. As opposed to the two above provisions, which result in a deferral of the tax payment, the depletion allowance represents an absolute reduction of tax payable and is not recoverable by the government in the future. Until the end of 1976 the depletion allowance will continue to be ⅓ of taxable income from oil and gas production. However, as of January 1, 1977, an "earned depletion" concept will be adopted which will allow the deduction from taxable production income of \$1 for every \$3 of eligible exploration expenditures to a maximum of ⅓ of the production income. The base of these eligible expenditures may be determined from expenses accumulated after November 7, 1969, which means that the practical impact for the frontier activities of most oil and gas companies may not occur until sometime in the mid-1980's.

This overall system creates a favourable tax climate for the petroleum industry in comparison with, for example, the manufacturing industry.

Taxation of the petroleum industry in Canada is more favourable than most other countries in the world. The United States has a comparable system to Canada, but is somewhat more favourable in the case of high cost oil since the depletion allowance may be based on gross rather than on net production revenue. In the United States there is also more flexibility in expensing exploration costs since any taxpayer may deduct these costs from other income. Foreign exploration expenses are also deductible.

The Canadian tax system is not designed to capture a very high percentage of the economic rent. In most major petroleum producing countries the tax system is used as the primary method of rent collection from oil and gas operations. The advantage of certain of these tax systems is that they tax selectively. Profits from a "bonanza" discovery are huge and have a high tax bearing capacity. Profits from a marginal field may be very low or zero and are not taxed at all. In countries where the effective tax rate is 55% or 60% the governments are certain to capture a large share of the rent. This is particularly true where taxes are calculated on the basis of artificially high posted prices or tax reference prices, as in most OPEC countries.

Federal Land Regulation Provisions

Before the federal rent collection mechanisms of bonuses, royalties, rentals and relinquishments are dealt with it is useful to review briefly the regulatory structure under which these provisions operate.

The regulations under which the federal government makes oil and gas rights available for development are the Canada Oil and Gas Land Regulations, which apply to such rights in the offshore and in the Territories. They were promulgated under the Public Lands Grants Act and the Territorial Lands Act. These land regulations are currently under review. No new federal permits have been granted since March 1972.

Before undertaking exploration work of any kind a party must first acquire an exploratory licence. A licence is non-exclusive, that is, other parties can be exploring the same area. It is renewable on an annual basis. A party may apply to carry out exploration work in any region including areas held under permit by other parties. A licence does not however, permit the drilling of a well. The concept here is to allow work throughout the federal territories and at the same time maintain control over all activities through operational and reporting requirements.

The second entity in the Canadian system is the exploration permit. A permit, in contrast to a licence, does involve certain exclusive rights. An authorization to drill a well within a permit area can be obtained only by the permittee, and only the permittee has the option of selecting oil and gas leases from a permit area. Permits may be issued directly to an applicant if an area has not already been held and surrendered back to the Crown. Where circumstances make it desirable to do so, original permits in an area may be issued by way of sale through public tender.

The emphasis at the permit stage is on exploration work; the discovery of oil and gas deposits. Permits have defined time limits. For example, offshore permits are valid for six years, with six renewals each of one year. The permittee must make a guaranty deposit at the time of issuance of each permit to the full amount of the specified work requirements for the first period as a surety that the work will be carried out. Similarly, guaranty deposits must be made prior to each succeeding work period. Permit work requirements increase progressively so as to reflect the progressive increase in expenditures necessary to effectively evaluate an area, from relatively inexpensive reconnaissance work, through detailed geophysical surveys, to high-cost exploratory drilling operations. Guaranty deposits are returned upon receipt of satisfactory evidence that appropriate work has been performed—they are subject to forfeiture otherwise.

The third entity in the Canadian system is the exploitation lease. Commercial production cannot be undertaken while acreage is still in permit form, it must first be converted to lease. It is at this stage that the emphasis is placed on revenues payable to the Crown, primarily through royalties on production and annual rentals. A permittee may acquire leases covering up to half the area of a permit with that portion not converted to lease reverting to the Crown.

There are certain 'Canadian participation provisions' that apply to the lease stage. In accordance with these provisions, for example, any individual wishing to obtain a lease must be a Canadian citizen, and any company wishing to obtain

a lease must be incorporated in Canada. The Regulations stipulate further that the Minister must be satisfied with the opportunity Canadians have for participating in the financing and ownership of corporations involved in applications for leases.

Permit or lease acreage reverting to the Crown through expiry, cancellation or surrender, thereby becoming what is commonly termed Crown reserves, may be re-issued as single permits or in blocks or permits by way of public tender, on either a cash bonus or a work bonus basis. Reverted acreage may also be re-issued in lease form through public tender—utilizing such methods as work bonus, cash bonus, cash bonus with an undertaking to drill a well—and the terms and conditions of such leases are as the responsible Minister may determine.

The following sections discuss the above-described federal government rent collection mechanisms in relation to similar provisions in other oil producing jurisdictions.

Bonuses: Many governments require the payment of a bonus at the time of granting of an exploration permit or concession or at a particular time during the exploration or production phase for an area. Some countries require a fixed bonus per service area. In the United States and recently in the United Kingdom bonuses are tendered by industry in the form of sealed bids. Alberta frequently holds crown reserve and other sales employing the same technique. Generally, permit areas are issued to those who offer the highest bids (in some cases the highest bid may not be accepted if it is considered to be too low). In areas where important discoveries have been made, such bonuses can be rather high. For example, in the Alaska lease sale following discovery of the Prudhoe Bay field, the State of Alaska collected about $900 million in bonus bids on 413,000 acres. Acreage bonus prices paid in Alberta for "Crown Reserves" have ranged from a few dollars per acre for rank unproven land to a record high of $19,400 per acre for a single small tract of land in the prolific Bonnie Glen field.

In other countries, particularly in the Middle East, bonuses are required at particular points during the production life: upon discovery of a commercial field for example or when a field reaches a predetermined production level. In Canada, bonuses are not required by the federal government at any stage of the operations. However, the government can offer for public tender lands that are returned to the Crown or deemed to be Crown reserves. Sealed bidding is a flexible means of earning a larger share of the rent. Bonus bidding however, is only an effective rent collector after significant discoveries have been made and where the industry has good general knowledge of an area's potential. It would be inappropriate for much of Canada's unknown frontier at this time.

Rentals: Annual land rental payments are not required by the federal government during the exploration phase although they are paid in the provinces and in most other countries. In general, rentals are not charged to earn a part of the economic rent, but to encourage a rapid evaluation of the acreage and to deter speculation. In some countries, the rentals increase each year. For example, in the United Kingdom rental payments are 25¢ per acre for the first six years increasing every year thereafter until the 17th year when they reach almost $3.00 per acre. These are, of course, relatively small payments, but if one realizes that the federal government has over 800 million acres under permit, then even such small

payments could contribute significantly to Canadian federal income. Federal regulations require rentals during the production lease period of 50¢ per acre in the first year, and $1 per acre in subsequent years. These rentals can be reduced to a minimum of one-half of this value by offsets against royalty obligations and various other methods.

Royalties: Royalties on both oil and gas produced from federal lands in Canada are currently set at 5 per cent in the first 3 years of production and 10 per cent thereafter. In most other countries in the world and for land under most provincial jurisdiction in Canada, royalties are higher. In most OPEC countries, royalties are 12.5 per cent. These royalties are not based on the wellhead prices as in Canada, but on an artificially high posted or tax reference price. On federal lands in the United States, royalties of 16.7 per cent are required. In some countries, royalties are calculated according to a sliding scale related to the volume of the production per well or per acre. The sliding scale allows the payment of low royalties, for example 5 per cent, if the oil or gas production per well is low and larger royalties, say 16 per cent or more, if the production per well is high. Thus, high royalties are paid on more profitable fields. Obviously this is a more flexible and more efficient system of earning rent than the flat royalty payment. There is provision in the Canadian federal regulations to reduce royalties on a property by Order-in-Council when it can be demonstrated that such action will allow a field to continue production. There is no similar provision to increase royalties in the event of a very productive discovery.

Relinquishments: Under most land regulation systems permit holders must relinquish acreage at the end of the exploration period or even prior to its end. In the United Kingdom, half the exploration acreage must be relinquished after 6 years. The idea of these relinquishment provisions is to prevent speculation and encourage exploration activity. Further, if important discoveries are made in particular areas, the value of relinquished lands can be substantial. The government can earn additional money by offering these areas for bonus bidding or by other means such as additional royalty provisions. In Canada, a company can only obtain a production lease for one-half of the exploration permit area. The federal government applies a system which controls the pattern of the permit areas which can be selected for lease by a company and which makes it likely that more valuable land will return to the government than is the case in most other areas of the world. Consequently, it is possible that on relinquished lands, portions of oil and gas fields may occur. In some cases, of course, the lands that are returned may not contain oil or gas. However, barren or productive, these lands can be offered for public tender, or disposed of in other ways so as to increase rent collection efficiency.

State Participation: A portion of the available economic rent could be earned directly through state participation in oil and gas operations. The Canadian federal government is already involved in a joint venture company; Panarctic Oils Ltd., in which it owns a 45 per cent participation. Wholly state-owned exploration and production, transmission, marketing or fully integrated oil and gas companies are now common throughout the world.

It must be recognized that direct industry involvement carries with it the exposure to risk which is not the case under simple tax and royalty systems. Risks will be particularly high in the exploration segment of the industry. Although potential rewards may be large, they are by no means assured.

The entire state participation issue is discussed in detail in Chapter 7.

Important Considerations

It is important to distinguish between economic rent collection efficiency and the total amount of rent available. If there is rent available from the production and sale of resources, a government should attempt to obtain a high percentage of this rent. As stated above, a flexible system is needed to achieve this result. However, if exploration and production costs are high, the total rent available may be small. The amount of rent available depends entirely upon industry costs and market prices. A comparison of Canada's tax and royalty system (including land regulations) with that of other nations is not meaningful if such a comparison is divorced from comparative economic analysis. What may be an appropriate system for one country, could be crippling for another depending upon cost and price conditions.

With regard to Canada's frontier resources, estimates of costs and prices that determine the magnitude of rent available are at this point in time subject to great uncertainties. Fiscal terms designed to obtain a very high percentage of the rent (say, 90 per cent as in Middle Eastern countries) which are based on preliminary rough approximations, may exceed the eventual tax capacity of the resources and reduce investment activity below desirable rates. In the early stages of exploration and development, therefore, before the economic nature of the resource base is well-known, it may be wise to set terms to yield a more modest rent collection efficiency. If the government wishes to ensure a continued strong investment pattern, great care must be exercised in establishing fiscal systems so that they take into consideration varying conditions throughout the potential producing area.

Clearly, fiscal terms do have a significant effect upon industry motivation and investment decision. If rent collection is increased, it is likely that a decrease in oil and gas exploration will result. If, in the government's view, the rate of resource development is too rapid, then a decrease resulting from increased government take may, however, be beneficial from the country's overall economic point of view. This is not to suggest that fiscal terms are the only way to moderate or to encourage resource development activity. Other regulatory tools are available and may be preferable in some respects. "Stop and go" fiscal terms create havoc with industry planning and difficulties in administration. On the other hand, regulatory controls such as land regulations and export policies, can significantly affect investment activity. Changes in government policy in these areas are fairly easy to institute. Influencing the development rate through land policy in Canada is, however, complicated by the fact that a very high percentage of federal lands have already been given out to permit. Under the present statutes, this situation leaves little leeway for effective action unless new legislation is introduced.

If it is determined that the fiscal system used in Canada is no longer adequate, it must be replaced with one which reflects Canadian conditions, not those which may exist in other unrelated parts of the world. While it is possible to benefit from the experience of others, the final product must fit the Canadian scene.

Rent Collection by the Consumer

An entirely different way of providing the benefits of economic rent to a nation would be to provide low cost energy to the consumer. The prices of energy commodities can be regulated or fixed below international competitive market prices thus reducing overall energy industry profits and passing on the benefits to consumers. The most outstanding example of this situation is in the United States where wellhead gas prices have been regulated by the Federal Power Commission for almost 20 years. The general concensus of opinion is that F.P.C. control over wellhead gas prices has contributed to the current energy problem in the United States. This policy has been criticized by an increasing number of energy industry spokesmen and others on many grounds. Recent changes in natural gas policy in the United States call for a complete deregulation of all prices for new gas entering the inter-state market and for prices being renegotiated under old contracts.

If Canada were to develop a system in which gas and oil prices were maintained below international prices for competitive energy resources, Canadian industry and the Canadian consumer would benefit. A lower energy price to industry, presumably lower than the prevailing world or U.S. price, has been put forward as one way Canada could build and expand its industrial base. However it would be difficult to visualize prices remaining significantly below international price levels given our future domestic needs for high cost frontier resources. The influence which a small price advantage might have in encouraging new industrial development would vary from industry to industry. Chapter 3 of this Section deals directly with the importance of energy costs to industry. With regard to the Canadian energy industry itself it should be noted that internationally competitive oil and gas prices will probably be a necessity if the full potential of the estimated frontier resource base is to be economically attractive to private enterprise developers.

Natural gas is our cleanest, most convenient fuel. Significant resources of gas will be found on federal lands, but for most of this gas the transport cost to our industrial heartland will be high. Even if this gas were provided on a cost of service basis, the cost would still be considerably higher than today.

The benefits of lower energy prices are: greater disposable income for the individual consumer, lower production costs to industry and hopefully lower cost products for Canadian purchasers. The problems associated with this system of rent collection relate primarily to the mechanism required to maintain low energy prices and can be illustrated by reference to the natural gas industry. Firstly, the basic market forces of supply and demand would be disturbed. This may not be detrimental to the economy as long as low cost energy resources are abundantly available. However, if such resources became scarce, drastic and costly adaptations to the new supply conditions might become

necessary. Oil and gas are non-renewable resources that require continuing high levels of investment in the exploration phase of the industry to replenish the supply of available reserves. If prices were held too low it would not only encourage the profligate use of these resources, but might serve as a strong disincentive to oil and gas exploration companies in their endeavours to discover new reserves. This has apparently been the case for the United States gas industry. A fine-tuning of prices would obviously be required.

Secondly, a low price represents a rather inefficient rent collection system, comparable with a flat royalty, unless a system is invoked whereby each gas producing company is offered a unique price based on its cost of services. The determination of each company's costs is an extremely complex and administratively burdensome task. It can lead to such anomalies as "split" gas pricing in a single well, i.e. where ownership of a well is split between two or more companies, each incurs a different cost of service and is remunerated accordingly. One step removed from the individual company cost of service is the area pricing system whereby all producers in a certain area receive a common wellhead price. Although this system is somewhat less burdensome administratively, potential inequities remain since high cost and low cost producers are treated identically. Rent collection under these circumstances would also be inefficient.

Thirdly, low cost gas would not be made available to a wide variety of consumers unless the distribution of gas were also controlled. If distribution were not controlled, large volumes of low cost gas might be used by Canadian industry for low-priority end use such as boiler fuel.

In the case of oil, problems similar to those described for the gas industry occur but, in addition, the administration of oil product prices becomes much more complex. Not only crude oil field prices, but also a wide range of oil products such as gasoline, naphtha, jet fuel, gas-oil, light fuel oil, heavy fuel oil, asphalt, etc. would have to be controlled at each stage in the refining and marketing chain. The regulation of rates of return on pipelines, refineries, wholesalers and retailers would be necessary to make such a system work.

Accordingly, if a price control mechanism is to be seriously considered as a means of collecting economic rent, then one has to envisage a very extensive government involvement in areas which to date have been controlled largely by competition in the market place. Wellhead and perhaps consumer prices for oil and gas would have to be set by the appropriate government (federal or provincial). This, of itself, raises complex problems. Obviously, the government of a producing province will want to set the maximum possible price at the wellhead while the governments of the major consuming provinces will want to set low end prices for their consumers. Further, to prevent our export customers from benefitting from the controlled low domestic prices a "two-price system" would be required. As discussed in Chapter 8 of this section this could be realized either through an export tariff or an energy marketing board.

Controls of this nature, in addition to the present control mechanisms, would clearly require close cooperation between the federal and provincial governments. The appropriate wellhead prices would have to be in harmony and some mechanism would have to be agreed upon to distribute the revenues flowing from an export tariff or a marketing board. Unless such close cooperation

were maintained the results of any price control mechanism could be self-defeating. Lower prices for natural gas, for example, could result in an inefficient use of this preferred fuel and a high demand could develop, including a significant amount of low priority and/or wasteful usage. There would be less motivation for developing and placing in use more efficient means of using our energy resources. End-use controls by the appropriate governments might have to be an integral part of any major move to control energy prices.

It is perhaps worthy of note here, as well as in Chapter 7 which deals with state participation, that greater government involvement, be it by direct or indirect means, should not be considered as a panacea for increasing energy costs. As an example, the direct role of provincial governments in the provincial electrical utilities has not been able to prevent recent significant increases in power rates.

Concluding Observations

A review of Canada's present rent collection system is necessary if Canada is to realize the full benefit of the development of its frontier oil and gas resources. A number of methods exist to create a more efficient rent collection system in Canada. The value of the economic rent available will depend on the prices of oil and gas, the cost of exploration and production and on the rate of resource development. While fiscal terms can affect the rate of development, other regulatory control measures should be used if the government wishes to control the activity rate.

Increased economic rent could be collected either by the consumer in the form of regulated low oil and gas selling prices, or by the government in the form of increased oil and gas tax and royalty collections from the producing segment of the industry. The collection of rent by consumers through controlled low energy prices would result in benefits to Canadian industry and to the population in general; it undoubtedly would have a beneficial impact on the competitive nature of Canada's export industries. On the negative side, a price control system, if applied to all energy uses, could result in anomalous upward pressure on demand due to low energy prices, would be very difficult to administer because of the large number of products to be regulated and, finally, could result in a significant disincentive to explore for and develop new sources of oil and gas supply. It could also raise major problems of a federal-provincial nature.

Alternatively, a larger share of the economic rent available at the production stage could be collected by increasing and improving the flexibility of the current royalty rate or by decreasing the current depletion allowance or both. These payments could be accrued by government in the form of a fund which could then be selectively used to benefit important or needy sectors of the Canadian economy. Such a system would be administratively simpler to operate and the selectivity of benefits distribution could result in a more efficient use of the revenues this obtained. It possesses, however, the same disadvantage as a regulated low consumer price, in that it could result in significant disincentives to the oil and gas exploration industry. In addition, the financial benefits obtained under this scheme would not be readily apparent to the average consumer who would see no reduction in his energy bill.

The federal government's land regulation program is presently under review in its entirety and no new federal permits have been issued since March of 1972. This review should lead to a more flexible and therefore more efficient rent collection system. At the same time however, a fine balance must be struck with regard to the desire for greater federal government revenue and the need to keep industry attracted to the task of establishing the frontier resource base of Canada and bringing the oil and gas to the market place. Any comparison of Canada's fiscal terms—taxes and royalties—with those existing in other countries must be used with considerable caution. Development costs and market conditions differ markedly throughout the world and appropriate fiscal terms in Canada must be designed to reflect the widely varying economic nature of our resource base and the current stage of development.

It must also be remembered that at the present time there is virtually no frontier production and only a few significant discoveries. The government has not earned any significant revenues from the frontier and is unlikely to earn any in the next few years.

At the same time as the federal review of the efficiency of its land regulations is proceeding, two other events are taking place which are of more immediate concern to the total national assessment of rent collection from our energy resources. Higher prices are being set by the Canadian petroleum industry for oil produced from established western Canadian reserves, and the Alberta Government is moving to increase its rent collection from both oil and gas resources. In the case of gas one thrust of the Alberta policy is to increase the price of gas at the wellhead and thereby achieve a greater financial return through the existing royalty structure. Industry obviously benefits at the same time through this measure and while the absolute value of royalty payments to the Alberta government may increase, the efficiency of rent collection, expressed on a percentage basis, would in fact decline unless this action was accompanied by an increased royalty structure. The Alberta government has announced its intention to do this.

The price movements have led to increasing suggestions of price controls on energy; controls which would not only keep Canadian energy prices down but would also differentiate between domestic and export prices. The price increases for both oil and gas appear to be driven to some considerable extent by international price pressures, particularly those within the United States. A system is sought whereby the opportunity price can be achieved in the export market without undue price increase to the Canadian consumer.

All these forces may well result in a combination of rent collection systems; federal land regulation changes, provincial royalty changes, and a two-price system for domestic and export consumption. If truly efficient rent collection on a national basis is the goal then obviously joint and complementary action is required by the federal and provincial governments.

Chapter 3

ENERGY AND EMPLOYMENT

Energy developments provide employment in jobs directly related to the exploration, production, transportation and sales aspects of the industry. They also support a large manufacturing and service industry base spread across Canada. Employees either directly or indirectly employed induce further employment in the economy through the spending of salaries and wages.

Jobs associated with energy often benefit those areas of Canada where other significant opportunities are lacking. Benefits cannot be adequately assessed on the basis of a "national average".

Canada's labour force will keep expanding rapidly during this decade but the growth should slow down in the eighties. Therefore large-scale energy projects related to frontier development, projects that would be required by domestic energy needs in the eighties, could be better handled and perhaps create greater overall benefits if started during this decade. A gradual, rather than rapid expansion would enable a larger degree of Canadian content.

There are four aspects of employment of importance to an energy policy: the direct employment, the indirect and induced employment, the regional employment and the long-term development of Canada's labour force. These aspects should be reviewed in the light of the resource base and rate of development observations made in previous chapters and, in turn, should be recalled when considering the short term and macro employment aspects of various development possibilities referred to in Section IV.

Direct Employment

More than 150,000 people are estimated to be directly employed in the energy sector. This employment includes that in coal and uranium production; hydro, nuclear and fossil fuel based power plants; oil and gas exploration and production; pipelines and other transport and storage projects; refining; gas processing; distribution of electricity and natural gas as well as fuel dealers and gasoline services; maintenance and repair and other customer services.

As can be seen in Table 1, there is a significant variation in the number of directly employed people in various energy industries. Direct employment in coal mines is relatively high, even in comparison with other activities in our society, while it is low in the case of petroleum refining. However, the level of direct employment per million dollars of output is not a very useful guide on which to make employment decisions because, as is well-known, the production of coal in

TABLE 1

THE EMPLOYMENT IMPACT OF PRODUCTION
(per million dollars of output)

	Employment Direct	Indirect[1]	Total	Multiplier[2]
Mining				
Uranium	19	24	43	2.3
Coal	98	30	128	1.3[3]
Petroleum and gas wells	10	35	45	4.6
Services for mining	39	44	83	2.1
Manufacturing				
Pulp and paper	46	97	143	3.1
Petroleum refining	5	37	42	7.8
Motor vehicle manufacturing	9	65	74	8.2
Utilities				
Electric power	19	33	52	3.7
Gas distribution	35	28	63	1.8
Construction	39	79	118	3.1
Transportation				
Truck	46	48	94	2.1
Pipeline	8	24	32	4.2
Rail	67	46	115	1.7
Services				
Retail trade	92	43	135	1.5
Chartered banks	81	36	117	1.4
Professional business	111	37	148	1.3
Other Services[4]				
Education	135	68	203	1.5
Hospitals	148	74	222	1.5
Recreational	74	37	111	1.5
Laundries and cleaners	85	43	128	1.5

[1]Indirect employment includes induced (that generated by the spending of wages and salaries).

[2]The employment multiplier is the ratio of total employment to direct employment.

[3]A recent study of the western Canadian metallurgical coal industry arrived at an employment multiplier of 4.9 during the operation phase.

[4]For those "other services", direct employment is known and a multiplier representative of some service industries has been applied to obtain an estimate of indirect and total employment.

SOURCE: Derived from Statistics Canada, Input-Output data (1961).

Eastern Canada has its economic problems and the labour involved is consequently declining. What is important for employment generation is not only the number of directly employed persons per million dollars of output, but also the profitability of the various industries. The work force in a certain industry will only grow if the industry is profitable and with expanding markets.

Public assessments of the potential social benefits of proposed industrial development has tended to concentrate on direct job creation. It cannot be disputed that the direct employment generated per dollar of energy sales is in general low

relative to some manufacturing or service industries. This does not, however, prove that an increased allocation of resources to the energy sector is less efficient than a comparable allocation of resources to more labour intensive industries. Consideration has to be given to the three other areas of interest that were mentioned earlier: the indirect and induced employment, the regional employment and the long term development of the labour force. The evaluation of an energy project should be viewed from the longer term perspective rather than just from the point of view of short term employment benefits.

Indirect and Induced Employment

Examples of *indirect employment* associated with the energy industries are pilots transporting exploration crews into the Arctic, lawyers representing energy firms, public servants in duties related to the energy industry, employees in the manufacturing companies making equipment for energy projects such as nuclear reactors or a high voltage transmission line, and many other jobs that are related to energy industries.

Induced employment is created when salaries and wages are spent by workers that are directly or indirectly related to the energy industries. For the economy as a whole it does not matter whether a sector provides jobs for persons either directly, indirectly or induced. Table 1 indicates that during the operation phase of energy projects, direct, indirect and induced employment is considerably higher than the direct impact alone. However, it is still not as high as in the case of some manufacturing and service industries. Apart from the operation phase, however, it is necessary to look at employment effects during the construction phase. These important effects are discussed in detail in Section IV of this report.

Regional Employment

The energy industries create important employment effects in certain regions in Canada that do not presently benefit from a high degree of manufacturing concentration. Consider the examples of Alberta, the Maritimes and the North.

Alberta

Alberta has had the second fastest growing population in Canada over the last 25 years and there is no question that this growth is largely due to the development of the petroleum industry. Since the discovery of Leduc in 1947 it has been the petroleum industry which has changed an economy based almost entirely on agriculture to one having a much broader base.

Some reports suggest that as much as one-half of Alberta's labour force is related to the petroleum industry through direct, indirect or induced employment. Alberta, however, is a "mature" oil and gas producing area. As has been discussed in Section II of this report dealing with the supply and demand of energy, it is expected that oil production from conventional Alberta reserves will start to decline in the late 1970's and gas production in the early 1980's. Alberta is now faced with the problem of developing alternative employment opportunities while still maintaining a substantial role in the servicing of oil and gas activities taking

place in northern Canada. If the development of the north and of Alberta's oil sands can be phased in effectively there should be increasing rather than decreasing opportunities for employment in the petroleum industries. Measures requiring an acceptable level of Canadian content in the service industries and in research and development activity will contribute to this objective.

The Maritimes

Nova Scotia and New Brunswick are faced with the problem of declining employment in their coal mines and it appears that this trend will continue as inefficient mines are phased out. If the offshore petroleum or gas potential of the east coast develops to the point of substantial oil or gas production, it is possible that a further reduction of coal production could result as either gas or residual oil replaces coal for heat generating purposes. Only metallurgical coal could then find economic markets.

The development of an offshore petroleum industry however, could offer a major stimulus to local industrial development given the proper federal and provincial policies. The industries in the Maritimes are already providing equipment and services to the offshore exploration activities although the extent of the contribution at the moment is limited mainly to the shipbuilding industry. It can be expected that the Canadian content of offshore operations and especially the local content in the Maritimes will increase significantly if a continuing development of the petroleum and gas production on the east coast takes place. As is often the case in new exploration areas, most equipment is initially imported and it is only when economical reserves are discovered that there is a strong incentive for the industry to build up a strong local infrastructure.

It is of great importance to Canada to move to establish permanent industries in the Maritimes that can be competitive in both local and world markets on the basis of the potential developments on the offshore east coast. In view of the fact that Canadian labour costs are, in general, high in comparison with other countries in the world, competitive Canadian industry is therefore only possible if it concentrates on the development of special equipment that shows a considerably better performance than other equipment in the world. Canadian research and development should concentrate on developing such special technology. One possibility relates to the development of drilling and production equipment that is suitable for operation in very cold waters with depths of between 500-1,500 feet. There would be a potential export market available if Canada could develop equipment that shows a superior performance under such conditions.

If large amounts of commercial natural gas were discovered in the eastcoast offshore, it could lead to a considerable economic impact onshore, solely through the conversion of many thousands of households to natural gas and all that that would entail in the form of the labour requirements for installing new equipment and for building the distribution network. In addition, the manufacturing of gas furnaces, gas stoves, and gas water heaters could have an important impact on employment in the Maritime economy. A coordinated approach by the Maritimes, the federal government and the petroleum industry could clearly increase the possibilities for improved local employment in this area.

The North

In the Canadian north, there is a special concern. There is considerable unemployment, especially seasonal unemployment, amongst the largely native population. Energy development can help to solve this and other northern problems. It will only do so if it is carried out in such a way as to bring the maximum of social benefits to northerners, including a variety of employment opportunities and a higher quality of life while at the same time respecting the different northern cultures and customs and minimizing the environmental consequencies of such development.

The jobs created must be tailored to the needs of the people as well as to those of the development. Concepts such as "Hire North" and the use of community labour pools must be further developed so as to ensure the maximum participation of the native people. Job opportunities must not be limited to unskilled labour, but must extend to all levels of construction, operation and servicing and must include training programs, counselling services, family accommodation and other forms of special assistance so as to place the northern native on a level of equality with the southern white. The pace of development may need to be regulated to ensure these benefits, without which any northern progress resulting from this development will be illusory.

Development of the frontier resources in the north can be the key to the overall social and economic development of the Territories, but only if the priorities established by the Northern Development Policy 1971-81 are adhered to. These require a "people first" approach to all development activities coupled with a determination to minimize environmental consequences.

Long-Term Development of Canada's Labour Force

The growth of Canada's labour force is projected in Table 2. It is clear from this Table that the labour force will continue to grow quickly during the 1970's. However, this trend will start to decline rapidly in the early 1980's, largely because the echo effect of the post-war baby boom will fade away. If there is no substantial increase in immigration or a drastic upwards change in participation rates for women, younger or older men, it appears that unemployment problems will be easier to resolve in the 1980's than in the 1970's.

This poses a special problem with regard to the scheduling of energy projects. Canadian demand can be satisfied from conventional petroleum and gas resources and from existing and planned oil sands facilities for at least the remainder of the decade if exports of gas do not exceed present levels and if oil exports are carefully programmed to take into account the rate of oil discoveries and the construction of oil sands plants. However, from the early 1980's onwards, petroleum production in the provinces will show a steady decline and there will be a growing need for frontier oil and gas or oil production from oil sands. With regard to the development of these frontier resources, therefore Canada has two basic options:

To "boom" frontier development in the 1980's and build a major pipeline, resource railway or other transportation facility every 2 to 3 years, or

To promote a gradual development of the frontier resources in advance of domestic needs and build the transportation facilities beginning in the 1970's at a more leisurely pace.

TABLE 2

GROWTH OF CANADA'S POTENTIAL LABOUR FORCE

	(1,000 people)		%
1970	8,374		
		70–75	2.8
1975	9,630		
		75–80	2.6
1980	10,926		
		80–84	1.8
1984	11,747		

A gradual development of the frontier and oil sand production, beginning in the 1970's, might have definite advantages to Canada as compared to a rapid expansion of frontier development in the 1980's. The advantages could be the following:

The Canadian labour force expands quickly in the 1970's, but will not in the 1980's. As was observed earlier in this Chapter, and as will be commented on further in Section IV, the construction of energy projects contributes in an important way to employment. From an employment point of view, therefore, it might be logical to undertake large scale energy projects in the 1970's rather than in the 1980's so as to use the labour forces available and to avoid possibly greater pressures on the Canadian economy at a later date. However, major projects cannot be justified solely on such short term considerations and accordinly this factor would have to be assessed in the ligtht of other government objectives.

A gradual development of frontier oil and gas and the Canadian oil sands should allow the creation of a Canadian manufacturing and service industry that can absorb a significant share of the required expenditures. It should also facilitate the development of skills and of know-how for both the manufacture and use of highly complicated equipment. This would increase the total employment from the projects and also diversify employment opportunities. The development of complementary manufacturing and service industries takes time. Consequently, if Canada wants a large Canadian content in its energy related manufacturing and service industries in the 1980's, it should give the incentive to develop those skills and know how in the industry now by means of a gradual phasing in of the major new developments which will be required in any event to meet domestic needs in the next decade.

As noted earlier in this Chapter the economy of Alberta is heavily dependent on the oil and gas industries and if it was decided to defer further major developments of pipelines, northern exploration or oil sands development until the 1980's, there would clearly be a decline in that Province's economy. A rational phasing in of these major programs starting in the 1970's could assist in maintaining the present Alberta base and build on its present competence.

Chapter 4

THE ROLE OF ENERGY COSTS IN CANADIAN INDUSTRY

Industries in Canada enjoy lower energy costs than in many nations in the world. While the price of energy is increasing, the increases are in large part driven by factors which are international in scope and therefore affect all industrial nations. Canada's overall competitive advantage should not be seriously affected although we will not have the natural advantage of major new low-cost hydroelectric sites.

Energy costs can have a multiplying effect throughout the economy. For example, the cost of an automobile reflects energy costs in the mining of iron ore and steel making as well as the actual fabrication of the vehicle. When all these factors are considered it is found that some industries are major energy consumers. Fortunately, only a minor number of industries could potentially have their competitive positions threatened by energy price increases. These areas, however, include important industries such as pulp and paper, chemicals and smelting, most of which are involved in upgrading Canadian raw materials. The effect of energy costs on these industries must be closely watched and special measures taken if necessary. The rate at which price increases occur can be of particular concern.

It is clear that international oil and gas prices will increase further in the coming years. If Canadian prices are allowed to follow this trend, an important question needs to be answered: What would be the impact on the industrial structure of the Canadian economy or, more specifically, which economic sectors would be influenced and how might this affect their economic position?

The main conclusions are that:

Higher energy costs could place some industries in a very difficult position, and special action may be required to ensure the survival and growth of these industries which now account for about 1 per cent of Canada's real domestic product and 3 per cent of Canada's industrial production.

Higher energy costs could create problems for some firms in a number of sectors producing in the aggregate about 10 per cent of the real domestic product. The most important of these sectors are: agriculture, iron and steel mills, and pulp and paper mills.

Higher energy costs would not be of great importance to the competitiveness of the large majority of the other Canadian firms because increasing energy costs will also be experienced by competing countries.

Export oriented industries appear to be among the heaviest users of energy, including industries which upgrade Canadian raw materials.

Canada is in a favoured position among industrialized nations through its self-sufficiency in energy at a time when physical availability of certain energy forms is becoming increasingly important.

Canadian Energy Prices

Three sources of energy are of primary importance to industry: electricity, natural gas, and heavy fuel oil.

Electricity costs in Canada are in general low, largely as a result of our hydroelectric resource base. Electricity sold to industry has averaged slightly over 7 mills per kWh in the last few years. Electricity costs to industry have been somewhat lower than average in Quebec, Newfoundland and British Columbia, about average in Ontario and Manitoba, and above average in the other provinces. These costs are affected not only by the costs of generation, but also by the rate structures of the various utilities.

The prices paid by industry in the Prairie Provinces for natural gas are very low. Prices paid in Ontario and Quebec reflect transportation costs and in some cases are higher than the cost of supplies to competitive industries in the United States. In spite of this gas prices are competitive with international fuel oil prices in the Central provinces. Consequently, it can be said that the industries in Canada using natural gas pay prices which, at their highest, are fully competitive with laid down international fuel oil prices.

The prices of heavy fuel oil in Montreal and Toronto, and in the Atlantic Provinces, are competitive with international fuel oil prices after allowing for transport costs. In the Prairie Provinces, fuel oil does not play a significant role because industries have ready access to natural gas. However, while heavy fuel oil prices in Canada appear competitive on an international basis, this does not necessarily mean that those prices could not be somewhat lower. Lower prices might be achieved by improvements in transportation economics.

In general, it can be said that while industry in Canada enjoys lower energy costs than its counterparts in many other countries in the world, there are numerous exceptions to this depending upon the fuel in question, the pricing policies of the utility or government and the location of the industry itself, i.e. remote from or close to the fuel source. The cost of heavy fuel oil in Ontario is higher than in most of the heavily industrialized areas of the United States, but industry in that province is now relying more extensively on natural gas than on heavy fuel oil. Another exception would be the cost of electricity to the industrial areas of Canada as opposed to areas in the United States served by federal government electric power agencies, i.e., the Tennessee Valley Authority and the Bonneville Power Administration. Even these areas, however, are experiencing significant rate increases.

The Significance of Energy Prices to Canadian Industry

Direct Energy Costs

The cost of energy is one of the many costs that are associated with the production of a wide variety of goods. Some industries are energy intensive, such as pulp and paper, metal smelting and refining, cement manufacturing, iron and steel and certain

chemical industries. Most industries however do not spend a large percentage of their costs directly on energy in the production of their final products. Table 1 indicates the direct energy inputs per dollar of output in the top direct energy users.

It should be noted that Table 1 refers only to energy that is actually purchased. Some Canadian industries, especially the aluminum industry and the pulp and paper industry, generate considerable amounts of electricity themselves, and while this electricity is a cost to those producers, it is *not* included in the tabulation except in cases where the fuel is purchased for generation. Consequently, for those industries that do produce electricity themselves, the costs are higher than shown.

TABLE 1

TOP DIRECT ENERGY USERS

Industry	Direct energy input per $ of output of the industry	Electricity	Fuels
Cement and lime manufacturing	11.3	3.1	8.2
Other chemical industries	10.4	0.6	9.8
Iron and steel mills	9.0	4.2	4.8
Asphalt roofing	7.9	1.8	6.1
AO-Non-metal mines	6.9	1.3	5.6
Other Non-metal minerals	6.1	2.1	4.0
Pulp and paper mills	6.0	0.7	5.3
Agriculture	5.8	4.9	0.9
Clay, stone and refractories	5.7	0.3	5.4
Coal mines	5.7	0.4	5.3
Other metal mines	5.6	3.7	1.9
Fishing and hunting	4.7	1.6	3.1
Plastic resin manufacturing	4.6	0.1	4.5
Transport and storage	4.4	0.5	3.9
Other wood industries	4.3	0.7	3.6
Asbestos mines	4.3	0.6	3.7
Iron mines	4.0	0.8	3.2
Wholesale and retail	3.1	0.2	2.9

In the production of a number of chemicals, energy sources are very important either as energy input or as raw material. For instance, energy sources account for 31 per cent of the cost of producing synthetic rubber and 37 to 55 per cent of the production costs of chlorine, depending on the production method employed. For ethylene it is 70 per cent and for ammonia, 78 per cent. It is therefore obvious that the cost of energy is a highly important determinant in the economics of the manufacturing process of the large chemical industries.

In terms of absolute expenditures it is of importance to note that in 1969 the Canadian pulp and paper industry spent $200 million on energy. This represents an outlay for fuel and electricity considerably larger than any other Canadian industry.

Indirect Energy Costs

If energy costs increase, each industry experiences a direct impact. Higher costs could mean lower profits or the increase could be passed on to the purchasers of the industry's products. If cost increases are passed along, this could not only affect the industry's competitive position, but also could have a multiplying effect on other industries. For instance, iron and steel mills depend on iron ore from mines and the direct energy cost at the mining stage is about 4 per cent of total costs. Energy costs in iron and steel mills themselves amount to 9 per cent as the manufacturing process is more energy-intensive. A similar cumulative effect throughout the whole economy may be observed as prices increase. This is particularly important for those industries that either use large amounts of energy or that depend on products that are energy-intensive. These indirect effects can be studied with the help of the input-output analysis procedure. Table 2 shows the leading industries with regard to direct and indirect energy requirements per dollar of final output. If one compares Table 2 with Table 1 it can be seen that there are a large number of industries where the combined effect of direct and indirect costs is greater than 10 per cent of final output value.

TABLE 2

TOP DIRECT PLUS INDIRECT ENERGY USERS

Industry	Percentage Contribution to real domestic product (1961)	Energy required per dollar of final Demand: Direct and Indirect	Energy required per dollar of final Demand: Fuels only
		¢	¢
Other chemical industries	0.92	19.4	13.7
Asphalt roofing	0.05	16.9	14.3
Cement and lime manufacturing	0.20	16.2	9.9
Iron and steel mills	1.00	14.7	10.7
Plastic resin manufacturing	0.13	13.8	9.8
AO. Non-metal mines	0.52	12.5	9.2
Agriculture	4.53	12.4	10.7
Other Non-metal minerals	0.07	12.1	4.2
Paint and varnish	0.15	11.7	9.3
Vegetable oil mills	0.02	11.6	9.5
Pulp and paper mills	2.18	11.5	4.9
Clay, stone and refractories	0.12	11.3	6.9
Leaf tobacco processing	0.02	11.0	9.3
Dairy factories	0.48	10.9	8.9
Steel pipe and tube	0.12	10.4	7.0
Flour mills	0.06	10.2	8.1
Other wood industries	0.11	10.0	8.0
Meat processing	0.48	9.7	7.9
Total	11.16		

It can be seen that the pulp and paper industry experiences a considerable indirect energy cost. Energy, as previously noted, is a major factor in the economics of the chlorine and caustic industry and in 1971 the pulp and paper industry consumed over one-half of Canada's production of chloralkali.

It is useful to analyse separately the total direct and indirect energy requirements of industry for electricity and fuels. The second column in Table 2 illustrates that if electricity is taken out of the total, only four of the tabulated industries are left with more than 10 per cent direct and indirect fuel use. This illustrates the importance of electricity in energy supply to most Canadian industries.

These data are based on the 1961 input-output model of Statistics Canada. Since 1961, substantial changes have occurred in the Canadian energy economy. The most important change was the rapid decline of coal as an industrial energy source and the large increase of oil and natural gas. Energy is one of the relatively few commodities for which prices in current dollars have remained stable over the intervening period and, consequently, overall inflation characteristic of the economy did not occur in energy costs. Recent increases for energy, plus projected increases will change this situation.

It should also be noted that the figures given relate only to the value of the products when they leave the factories. After they leave the factories, they have to be transported to market centres and the direct and indirect energy use in the transport sector is 9 per cent. They then have to be distributed and the energy use in this activity could be around 4 or 5 per cent. Consequently, at the final consumer level, the percentage of energy costs will be somewhat different than indicated in the Tables. The absolute cost of energy in the delivered product will of course be higher.

Export Industry

There appears to be a correlation between energy use and exports. In general, those secondary manufacturing industries that export a significant amount of their production also use large amounts of energy directly. If indirect energy use is taken into account, this trend remains. For instance, the average direct energy use by all industries is 7.9¢ per dollar of output; the same figure for the exporting industries is 8.9¢ and for the import-competing industries, 7.2¢.

It is hard to judge how important the role of energy has been in the establishment of export industries. Although Canada has a large resource base, it must overcome great distances in shipping its products to market. Efforts must be made to achieve transportation economies and one way of doing this is to reduce the weight of the materials shipped. Weight reduction of materials is usually associated with a large use of energy, such as in the processing of mineral ores, or in the manufacture of newsprint. Such further processing of Canada's raw materials is an obvious national objective in view of the significant economic benefits which flow from it. Energy costs represent 4 to 20 per cent of the cost of converting raw materials to a higher level of value added and therefore are a significant factor in achieving this national objective.

While some of Canada's export industries are high energy users and energy costs naturally play a role in determining their success in the international economy, this role must be considered in relation to a whole host of other cost and productivity factors pertaining to the production, further processing, transportation

and marketing of our export products which, when taken together, considerably outweigh the effect of energy cost itself.

Regional Effects

The results of the input-output analysis suggest that the role of energy costs does not exceed 10 per cent of the cost of doing business for most industries in Canada. However, on a regional basis the impact may be quite different. There is no question that the availability of cheap natural gas in northern Ontario has played a significant role in the growth of industry in that area and it might very well be that, without the availability of this energy source, a number of industrial developments would not have taken place. For a number of areas, gas became available in large quantities at prices considerably lower than those for alternative fuels and this availability unlocked and enhanced new industrial possibilities. Similar benefits may be realized in the Canadian north. Mackenzie Valley gas could open up possibilities for local industries in the northern territories and thereby enhance the economic development of this large region for the benefit of the native people and other northern residents.

Effects of Price Increases

There is little doubt that energy costs will increase in the coming decade. In view of the fact that most electricity is already provided to industry from public utilities, which do not make a profit, or from generation plants owned by the industry itself, there is not much possibility of influencing prices, other than by direct subsidies. In this regard however, it should be noted that in terms of real costs, electricity prices should not increase dramatically over the period to the year 2000 and certainly will not increase at a rate comparable to oil and natural gas. Electricity prices in fact may well set the ceiling for the price of fossil fuels for many end uses.

Petroleum price changes in Canada will in part be influenced by government policy. Most price increasing pressures will have their origin outside of Canada and Canadian price increases will parallel those in the United States, Western Europe, and Japan, unless government policies are developed to insulate Canadian prices from these trends. In any event, and even without government intervention, energy price differentials among competing countries should not change radically.

As long as energy price increases are relatively uniform throughout the world they will probably not significantly affect total Canadian export potential. However, it might very well be that a few specific industries will experience considerable difficulty. Examples are industries that use large amounts of natural gas and are now faced with a relatively large price increase in a short period of time. The Canadian chemical industries that have to compete with similar industries, such as those in the Gulf Coast areas of the United States who operate on the basis of cheap intrastate "vintage" natural gas, may have some price adjustment problems. These problems will ease somewhat as the existing intrastate contracts expire and the United States chemical industries have to accept much higher renegotiated prices. However, in the meantime, some special attention may be required to ensure that Canadian chemical industries can adjust to new price levels. The rate at

which energy prices increase for all energy intensive industries must be closely monitored to assess the impact in relation to competing industries in other countries.

In view of the projected "gas gap" in the United States the longer term picture suggests that availability of new gas supplies rather than the cost of those supplies may become the overriding concern. This would be in spite of a priority given to the chemical industry's needs as opposed to other major uses such as boiler fuel. In Canada there should be no problem with the physical availability of natural gas to industrial consumers.

To summarize therefore energy costs, as a percentage of total costs, are not significant for the majority of Canadian industries. The exceptions however, include important industries such as pulp and paper, chemicals and smelting, most of which are involved in upgrading Canadian raw materials for both the domestic and export markets. While it is not expected that the cost of energy to these and other Canadian industries will exceed the cost to most world competitors, the opportunities for such energy-intensive industries must be a major element in any consideration relative to the possible insulation of Canadian energy prices from upward pressures in the United States and elsewhere in the world. As part of that same consideration would be the impact of such an insulation on the Canadian energy producing industries themselves, especially when they are faced with the costs of operating in the frontier regions of Canada.

The input-output studies have shown that other costs; such as labour, transportation, equipment and raw material costs, combine to provide a far greater impact on Canadian industry than does the cost of energy. All of these factors must be assessed when considering the competitive position of Canadian industry in the future. A competitive advantage in terms of energy costs obviously cannot, by itself, ensure the success of an industry.

Chapter 5

UP-GRADING OF ENERGY EXPORTS

Canada at present is an exporter of raw materials in the form of crude oil, natural gas, coal and uranium. The question is continually being asked —can't Canada "up-grade" these materials before they are exported? Many ideas have been broached and six possibilities are presented here.

Should Canada build a uranium enrichment plant even though CANDU reactors use natural uranium? The market would have to be in countries other than the United States which has a self-sufficiency objective.

The export of electricity rather than fuels is an important up-grading objective and CANDU reactors could provide the electrical energy.

The United States will be looking for additional imports of natural gas and Western Canada has the coal available for one or more gasification plants. Costs are high at present and there are technical problems to be overcome but the possibility over the long term cannot be ignored.

Can Canada export more petrochemical products in place of crude oil? Obstacles to overcome include the preference of the integrated oil companies to refine crude oil within the U.S. and the impact of the U.S. import fees.

Should Canada manufacture synthetic natural gas for export? Present plans call only for the export of the raw materials.

The petrochemical industry has problems with its limited market in Canada and the high U.S. import tariff. The high cost of feed stocks has also been a problem. However, the rewards of an expanded petrochemical industry are considerable and efforts should be made to rationalize this industry and find the necessary export markets.

Crude oil, natural gas, coal, and uranium are raw materials and considerable attention is directed to the question of whether these raw materials can be up-graded before they are exported. Such up-grading would contribute to greater industrial development and employment in Canada and therefore the economic wealth of this nation.

While electric energy is not considered as a raw material it too can be "up-graded" through its use by industry in Canada and the export of the resulting manufactured goods. Aluminum is an example of where considerable amounts of electrical energy have been used to develop an exportable commodity. The use of all energy forms by Canadian industry, and the sensitivity of industry to the cost of energy, has been discussed in an earlier chapter.

One can conceive of six realistic opportunities for up-grading energy exports: uranium enrichment, the export of electricity rather than fuels for United States generating plants, coal gasification, export of oil products rather than crude oil, the

export of synthetic natural gas rather than oil products, and export of petrochemicals rather than oil products.These possibilities are briefly reviewed hereunder.

Uranium Enrichment

There is a growing need for enriched uranium in the world for many decades to come. However, the CANDU reactor used in Canada is fueled with natural uranium and enriched uranium is not required. Consequently, a Canadian uranium enrichment plant would have to depend almost exclusively on the export market. Furthermore, it is unlikely that this export market would include the United States because of that country's desire to be self-reliant in this regard.

The gaseous diffusion process of enrichment is presently the only one being used on a commercial basis. If Canada were to obtain and use this technology, large amounts of electric power would be needed. As has been mentioned in Section II of this report, there are no really cheap undeveloped hydroelectric sites available in Canada which are close to our urban centres. Therefore, an enrichment plant would have to be located near a remote source of hydroelectric energy if it wished to have a significant competitive advantage through energy costs.

Alternatively, if the physical availability of energy and other aspects such as stability of government are factors which are important in the minds of the potential purchasers of enriched material, then an enrichment plant could be located closer to an urban centre and powered by a combination of electrical sources, including nuclear energy.

Assuming that an enrichment plant would be required to pay a competitive price for any energy purchased from a Canadian utility, so that it would not be penalizing other energy consumers, then such a plant offers an opportunity to turn energy into employment opportunities in a new industry. Furthermore, unlike the aluminum example previously referred to, Canada possesses the raw material required by an enrichment plant. To the extent that Canadian uranium was used in a Canadian enrichment plant there would be a further stage of up-grading of this energy commodity. At present Canada possesses the capacity to up-grade uranium ore to all but this last stage.

The construction and operation of an enrichment plant in Canada would have to be undertaken in a manner fully consistent with Canada's position on nuclear safeguards.

Exports of Electricity

Canada could use its uranium resources and its nuclear design capability to construct CANDU nuclear power reactors which would be committed in full or in part to serving a possible U.S. export market. However, there are a number of conditions which would have to exist to make this possibility a reality. Firstly, a United States utility would have to be willing to contract for power imports based on the dependability and cost of the "foreign" CANDU system. Secondly, Canada would have to be firmly convinced that any added environmental burden would be within acceptable levels and would not result in extra environmental protection costs being charged to nuclear plants required for domestic loads. Thirdly, Canadians generally, and the National Energy Board in particular, would have to be

satisfied that the export sales would be truly surplus to Canadian needs and in the public interest.

Assuming these conditions could be met, such an export of electrical energy would be a valuable way to up-grade Canadian energy exports using Canadian technology and labour.

Coal Gasification

The increasing demand by the United States for new sources of natural gas in the coming decades suggests the possible establishment of one or more coal gasification plants in western Canada to serve this export market. Currently, the production cost estimates for gas from coal gasification plants vary widely according to the process assumed and the optimism of the estimator. However, figures ranging from $0.80 to $1.30 per thousand cubic feet have been mentioned. These costs are obviously very high in relation to today's natural gas prices, but could become economic as more remote sources are turned to.

There are significant technical as well as economic problems to be overcome. If, for instance, the IGT Hy-Gas process were to be used in Canada, the smallest plant would require a reserve of at least 110 million tons of coal to sustain a production of 2 trillion cubic feet of gas over 20 years (100 billion cubic feet per year). Another problem is the large volume of water necessary to operate the plant. Over half a ton of water is necessary to react with each ton of coal. In addition, large volumes of cooling water are necessary for the thermal power plant which is used to supply the energy required for the production of oxygen and the compression of the methane into the pipeline system. There are probably not more than half a dozen sites in Canada where adequate coal and water resources are present together and in reasonable proximity to existing gas pipeline systems.

Apart from these technical problems it is very likely that there will be considerable environmental problems associated with coal gasification plants.

Canada's coal exports at present are limited to high grade metallurgical coal. It would seem that there is only a limited prospect of exporting other coals in the form of coal gas.

Petroleum Products

In 1972 Canada exported 422 million barrels of crude oil and petroleum products. Of this export volume 74 million barrels or 18 per cent was exported in the form of petroleum products. In the past most of the exported petroleum products were derived from Canadian raw material. However, in 1972 exported products based on imported crude oil amounted to 38 million barrels or 51 per cent of total petroleum product exports.

Should Canada move towards a larger percentage of our oil exports in the form of oil products? The main problem in the past has been the additional cost of transporting a number of oil products into a market area as opposed to transporting crude oil. It has been primarily for this reason that refineries have become largely market as opposed to resource oriented.

With increasing exports of crude oil from Western Canada to the United States it is possible that we are approaching the threshold level where sufficient

economies of scale could be realized to make the shipment of products economic. Such economies of scale would require industry cooperation in refinery construction and interference with the present practice of some producers whereby crude is exported to U.S. refineries owned by affiliate or parent companies.

The ability to export products would also depend upon the balance of the U.S. desire to have refining done in that country as opposed to its desire to have access to Canadian oil products.

The possibility of larger exports of oil products from Western Canada warrants further study in view of the rapidly expanding export levels. The effect of U.S. import tariffs on products would have to be reflected in such a study. The new U.S. oil import program is clearly designed to encourage refining within the United States through the imposition of a 63-cents-per-barrel licence fee on imported petroleum products.

In Eastern Canada major refinery expansion is taking place on the strength of the excellent deep-water port sites which are available. Such ports present economies of scale flowing from the use of very large tankers to import the crude supplies. While this expansion is producing employment opportunities to Canadians near the sites, a considerable percentage of the refinery equipment is being purchased from offshore sources. In addition, the economics of the operations are dependent on secure sources of crude, secure export markets and the continuation of the present policies of the importing nations.

Another consideration which must enter into all studies of further refinery capacity in Canada, is the acceptance of the potential for environmental damage. However, strict environmental controls could keep this potential to a minimum.

Synthetic Natural Gas From Oil Products

Synthetic natural gas (SNG) can be made from naphtha, natural gas liquids, or even crude oil. In view of the present natural gas shortage in the United States, a large number of SNG plants are being considered on the basis of feedstocks of naphtha or gas liquids. The costs are rather high. Canada has the option of exporting naphtha or gas liquids to the United States, or producing synthetic natural gas at home for export. The export of synthetic natural gas, if it can be done economically, would be a form of further processing of oil products. Currently, there is interest in the export of ethane from Alberta that would be used for the production of SNG in the United States.

The Petrochemical Industry

The Canadian petrochemical industry, located in Sarnia (about 50%), Montreal (about 40%) and Edmonton (about 10%), is an important industrial sector in the Canadian economy. It manufactures products from petroleum feedstocks which are subsequently converted into a growing range of items including synthetic textile fabrics, plastic and rubber products, paints and synthetic detergents.

Economy of scale is an important consideration as the Canadian industry must compete with the large scale plants operating in other countries. At present domestic producers face a limited domestic market due to large imports in the face of lower Canadian tariffs, and restricted export opportunities (particularly in the

United States) because of high foreign tariffs. This has resulted in small scale plants in Canada. These factors of market and scale, combined with high feedstock costs, have led to a steady deterioration in the competitive position of the Canadian petrochemical industry. Until these problems are resolved the industry will not be able to achieve reasonable growth.

The importance of the cost of energy, and feedstocks from energy products, can be illustrated by the fact that these costs are about 70% of the costs of producing ethylene and about 50% of producing vinyl chloride.

Canadian producers in the Montreal area draw feedstocks from world markets with only relatively small freight disadvantages compared to United States seaboard locations, but face the problem of moving the petrochemical products substantial distances to large markets. Producers at Sarnia although favourably located in terms of most markets, have problems because they are located west of the Ottawa Valley line.

It is for the above noted reasons that Chapter 4 of this Section acknowledges the special problems of the petrochemical industry.

Chapter 6

SCIENCE AND TECHNOLOGY IN ENERGY POLICY

New priorities and greater coordinated efforts in research and technology are necessary to assure Canada's energy needs through the transition years from fossil fuels to the nuclear era. Some special technological problems exist in Canada in the three key areas where major sources of oil and gas can be tapped—the Alberta oil sands, the Arctic frontier and the continental shelves. The oil sands present the scientific problem of extracting known oil; the principal technological problems in the Arctic are transportation and a delicate environment; offshore drilling presents the problem of protection of the sensitive and vitally important ecosystems over the continental shelves.

Scientific work has been somewhat isolated and scattered. A survey is under way to pull together information as it might relate to Canada. We have only a tentative knowledge of the extent of our energy resources. This too, is a vital area for accelerated research.

Looking ahead to the electrical age, research will have to aim at finding environmentally safe uses for the large amount of waste heat generated by Canada's successful nuclear energy generating system. The problem of assuring supplies of heavy water also must be solved. Techniques for transmitting electrical energy can be improved. Better methods for storing electricity (batteries) are necessary if electrical sources are to be in a position to assume the role of petroleum in such uses as automobiles. And, of course, Canada must keep pace with the worldwide search for new sources of energy.

Science and technology are tools for achieving our energy objectives. Coordinated and cooperative programs will be required involving industry, governments and universities if we are to make effective and timely progress in the solution of technical problems associated with energy development and use, and to ensure that energy resources are made available to Canadians at reasonable costs. It will be a measure of our science policy that Canada's limited scientific resources can be directed to meet this challenge, while at the same time not unnecessarily depleting those scientific resources required to meet Canada's other national and human objectives. In this chapter certain energy issues requiring the application of science and technology are identified. The formulation of major programs for their solution is left for further debate and action.

While Canada appears to have a substantial energy resource base on which it can call to meet future domestic needs it is clear that over the next 30 years there must be significant changes in traditional energy supply and demand patterns. As our readily accessible oil and gas resources are consumed we will need to locate

and develop geographically remote sources of hydrocarbons, or turn to alternative fuels. Similarly, our major coal resources and our remaining hydroelectric resources exist in areas of Canada remote from the large centres of consumption, and significant advances in the technology of energy transportation will be required to make these resources economic.

At the time these changes in our energy supply situation are taking place, Canada as a nation (and hopefully Canadians as individuals) are committed to improving the protection of our environment at every phase of energy production, transportation and use. Similarly, like other nations, we are beginning to comprehend the magnitude of our energy wastage through inefficient use. Though we may not be obliged to conserve energy in Canada because of physical shortages, the increasing cost of energy and the awareness of shortages in other nations will prompt a far greater concentration of effort on improving the efficiency of energy production and consumption.

The initial priorities for energy research and development must be addressed to fossil fuels as these are the resources which we will rely on to carry us through this century into the age of nuclear fusion and other "advanced" technologies. The ease with which we move through this transitional period will be dictated to a very large extent by our success in developing a far better knowledge of the extent, quality and accessibility of Canadian energy resources, and new and improved technologies to permit their efficient development, transportation and use with the least possible environmental disruption.

The present nature and level of energy scientific and technological activities in Canada is not widely known. Scientific activities in the petroleum sector are funded and performed in isolation from funding and performance in the nuclear, coal, or other energy sectors. A survey currently under way by the Science Council will give the first detailed overview of the overall distribution of scientific activities among the energy sectors, and hence a better understanding of gap areas. A 1971 preliminary review of federal R&D expenditures on energy indicated a heavy emphasis on nuclear energy (71% of the total federal funding for energy R&D) and considerably less on coal (13%), oil and gas (11%), electrical energy (4%) and oil sands (0.1%). The distribution of this funding should be reconsidered critically in the light of the priorities which emerge from this policy analysis.

Not only is the distribution of research priorities within the energy sector important, but energy research requirements and related environmental research must receive high priority within overall Canadian science policies, and be coordinated with the expected chronology of changes in the energy industries.

In view of the worldwide concern over energy requirements, large research expenditures are being made in many parts of the world, and it may be in Canada's best interests to import some of the resulting technology rather than attempt to develop it independently. On the other hand, some technological needs will be unique to Canada, particularly those associated with the development of the oil sands and Arctic resources and offshore resources located under Canada's huge, valuable and often environmentally sensitive continental shelves. This work should be carried out in Canada, as far as possible by Canadian institutions. A federal government Task Force on Ocean Policy is exploring the scientific and technological implications of offshore oil and gas exploration and production.

However, as matters stand, a considerable proportion of the research and development work performed by the multi-national energy companies operating in Canada is executed at centralized research laboratories and engineering departments located outside of this country. This is a natural tendency as it permits the concentration of specialized staff and physical facilities and economies of operation. However, viewed from the Canadian standpoint, it means a loss of employment opportunities within Canada in the scientific and professional fields and creates the risk of research which may overlook certain peculiarly Canadian environmental problems. In addition, when work progresses to the point where prototype operations or fully commercial operations are to be commenced, there is a strong tendency for companies to turn to the engineering and supply industries which have been involved with them at the research and development level. Accordingly, the carrying on of R&D activities outside of Canada is frequently the beginning of a chain reaction which sees not only the R&D, but also engineering and equipment supply being undertaken by non-Canadian industries. For these reasons it is important that a major effort be made to select specific areas of research and development needs in Canada in the energy field, and to take strong measures to see that facilities, personnel and funds are available to support these activities in Canada. Successful developments in energy science and technology will result in downstream participation by the service and manufacturing industries in the major capital outlays required to sustain Canada's energy requirements.

While industry operating in Canada can be expected to finance a large measure of the research needed, federal action will be required to coordinate and manage the overall research effort and to finance certain programs directly.

Priority Areas

Even a cursory examination of the supply-demand analysis presented in an earlier chapter of this Section will have indicated to the reader a continuing dependence on petroleum resources over the coming decades. It is these resources which will permit the relatively painless transition from the petroleum era to an electrical era based primarily on the consumption of uranium. Exactly how painless this will be in terms of cost to the consumer and impact on the environment will depend to a large extent on the success of our science and technology activities in two problem areas which are to a large extent uniquely Canadian.

The first of these relates to the development of the tremendous petroleum potential which exists in the Athabasca oil sands and other heavy oil deposits in Western Canada. Unlike the resources of the far north and the offshore areas, whose existence are not yet proven, Canadian oil sands are known to contain approximately 700 billion barrels of oil. It is not a matter of establishing whether or not the oil is there, but rather a question as to how we can economically and efficiently exploit what is one of the largest sources of petroleum in the world today. The development of an economical means of recovering the oil locked in the oil sands could very well set a ceiling on the price which Canadian consumers will have to pay for petroleum products in the years to come.

As the price being charged for petroleum increases so it will become economical to mine greater and greater amounts of oil sands by traditional methods. The

vast majority of the sands, however, are too far under the surface to be economically strip mined. Furthermore, the mining and processing of vast quantities of oil sands poses environmental problems to which adequate answers are not yet available. It is for these reasons that research and development related to the Canadian oil sands is considered a high priority.

The second major challenge facing Canada in the petroleum field is the development of techniques and equipment which will permit the efficient and safe exploration, production and transportation of the oil and gas resources of our Arctic landmass, the Beaufort Sea areas, and from the sedimentary basins lying deep below the waters off the east and west coasts. There are research and development opportunities here which will not only benefit the Canadian consumer through the provision of northern and offshore petroleum at lower costs, but also could greatly improve Canada's industrial role in offshore oil and gas technology.

The chapters of this report dealing with energy requirements and resources clearly illustrate the tentative nature of our understanding of the potential energy resources available in Canada. It is therefore obvious that a considerable effort must be made in the science and technology relating to the improvement of our inventory of these resources. Without improved technology much of the potential resources will remain unevaluated. Without this knowledge no really effective management system for our resources can be developed, nor can we define with any precision the time when this nation may be required to turn to new forms of energy development. This uncertainty about the full extent of our energy resource base also highlights the need to pursue the development of technology that will make more efficient use of the resources we have at our disposal, and thereby reduce the very considerable amount of waste now being experienced. Increased energy costs will add urgency to these efforts.

Our research and development activities should also take into account the problems posed by an eventual move into an "electrical society". Canada has developed a successful competence in the field of nuclear energy and we should build on this base for the future. This will require a better knowledge not only of the uranium resources available to the country, but also how these can best be put to use as new nuclear technology is developed. Emphasis will have to be given to the development of adequate systems for the disposal or storage of spent nuclear fuel and other radioactive wastes and for the efficient use of the large amounts of waste heat generated by nuclear power stations. In addition, an immediate priority is the resolution of the technical problems being encountered in the production of heavy water and which are now inhibiting a more rapid expansion of the use of CANDU reactors.

The success of the CANDU reactor may enable us to sidestep the era of the breeder reactor now emphasized so much in research programs in the United States and elsewhere. If this proves to be the case we can concentrate on improving the CANDU system with the intention of moving gradually into fusion research when the time appears appropriate. Since the CANDU system is a unique Canadian development, it is essential that we maintain an adequate safety program, since the safety programs in other countries are directed toward reactors of different design.

As we move towards greater and greater use of electrical energy, attention must be directed to the development of lower cost transmission techniques, more efficient and stronger interconnections between the major electrical utilities in Canada, and more efficient generation and use of electrical energy. A major challenge is the development of an efficient means of storing large quantities of electrical energy. For example, the development of a battery capable of freeing our transportation systems, especially in the urban areas, from the need to consume petroleum products, would not only decrease the depletion of our petroleum resources, but would resolve many of the air and noise pollution problems facing this and other nations.

Increased attention should also be given to the coal resources of the nation. Not only should we have a better understanding of the extent and quality of our coal resources, but we need to know much more about how they can be more efficiently mined, transported and used in a manner compatible with Canadian environmental standards.

Canada is also blessed with a significant potential for the production of electric power from the tides of the Bay of Fundy. While recent studies have indicated this power to be uneconomic, its renewable nature and the fact that it is non-polluting, warrant the continuing government study that is being devoted to it.

There are also a number of energy sources and conversion processes of less immediate concern. These include geothermal, tidal, wind and solar energy; fuel cells; the use of hydrogen as a fuel; magneto-hydrodynamics, and thermionics. For the time being it should be sufficient to keep abreast of work published in the open literature and to fund modest research proposals on a selective basis. Further discussion of these advanced technologies may be found in Appendix A.

Chapter 7

STATE PARTICIPATION IN THE CANADIAN ENERGY INDUSTRY

That the "state" has a proper role in the development and supply of energy is not a novel idea in Canada. Eight of the ten provinces own either all or the majority of the electrical utility facilities within their provinces. Federal government participation in the uranium and nuclear industries is very extensive from exploration and mining to nuclear plant design and operation. The proportion of state-held investment in the Canadian petroleum industry is less than 1 per cent of total investment in the industry but the federal government's 45 per cent participation in Panarctic represents a prominent position in frontier oil and gas resource development, and the Quebec Government's Quebec Petroleum Operations Company (SOQUIP) is the first provincial government oil industry operation. Although much of the coal industry is in private investment hands, state participation in the Cape Breton coal industry has been directed to important social and regional development objectives.

Many countries in the world have state participation in the oil industry and other sectors of the energy economy. In fact, countries with national oil companies are more nearly the rule today rather than the exception.

To those who feel that enhanced state participation in the petroleum sector is a desirable activity in Canada, their conviction may be simply expressed as a desire for Canadians to do their own thing with their own assets and in their own way. In more specific terms, the expectation would be that a national petroleum company would provide a window on the world for acquiring better information about the international petroleum industry and the domestic industry as well. It could be used to stimulate regional development, to coordinate research of a uniquely Canadian character, to determine economic rent objectives, to deal with state oil companies in other countries, and to assist in the development of "headquarters" activities within Canada.

The establishment of a successful national petroleum company in Canada would be expensive. Potential oil bearing land would have to be acquired and exploration work carried out. If petroleum were found, production, transportation, refining and marketing facilities would be required. The task would be a time-consuming one with no guarantee of success.

INTRODUCTION

Other chapters of this report make reference to the role of government in the management of Canada's energy resources, i.e. the role of the National Energy Board and the Departments of Energy, Mines and Resources, and of Indian

Affairs and Northern Development. There is also discussion of the possible need for greater government control if it is deemed desirable to insulate Canadian prices for energy from world trends or if greater conservation of energy is to be a major policy thrust. Over and above the discussions of the degree of government control, there are important considerations associated with the actual and desirable magnitude of direct government participation in the energy industries.

There already exists today a measure of government participation in sectors of the energy industries. Most of the electrical energy industry is under public ownership, primarily at the provincial government level, and the federal government participates in all phases of the uranium and nuclear energy industries, from mining to refining and sales and in nuclear design. On the other hand, much of the coal mining and nearly all of the oil and gas industry is not only controlled by the private sector, but much of that control is vested in foreign interests.

This chapter reviews the present participation of government in each of the energy industries and discusses the possible role of government, not in a control responsibility, but rather by direct participation in the activities of the various energy industries, from exploration through production, and transportation, to marketing of energy.

The Electrical Utility Industry

That the "state" has a proper role in the development and supply of energy is not a novel idea in Canada. The utility characteristics of the electric power companies; the efficiencies available from monopoly generation, transmission and distribution; and the absolute necessity of reliable and reasonably priced supplies of electric energy led to the early involvement of the Canadian provinces in nearly every aspect of the supply of electrical energy. At the present time, eight of the ten Canadian provinces own either all or the majority of the generation, transmission and distribution facilities for electricity within their own boundaries. Only in Alberta, Newfoundland and Prince Edward Island do these aspects of the electrical energy business reside to any degree in the private sector. In Alberta a significant element of the generation and distribution of electricity is municipally owned.

Table 1 illustrates the investment and participation of provincial governments, as opposed to the private sector, in the electricity supply industry.

A conclusion contained in the analysis of the energy requirements of Canadian society (Section II) is that the Canadian energy economy will be based more and more on electricity as time goes on. It is possible that by the year 2050, ninety per cent of Canada's energy consumption may be in the form of electricity. Consequently, the role of the state in the energy society, as illustrated by the role of most of the provinces of Canada, will grow larger and more significant by reason of their role in electrical energy alone. The provincial utilities, in order to service the anticipated load growth rates in Canada during the decade to 1980, are estimated as likely to require some $23 billion for capital investment. This is 46 per cent of a total $50 billion which the energy sector of the Canadian economy will need to invest in the same period. The percentage will grow in the following decades.

No significant change in the pattern of provincial government ownership of the electric utility industry is expected.

TABLE 1

CONTRIBUTION OF THE PUBLIC SECTOR TO ELECTRICITY SUPPLY 1970

	Capacity (kW)	Generation (MWh)	Total* assets ($'000)	Sales to ultimate consumers ($'000)
Public Utilities	33,019,906	151,406,533	14,096,000	1,974,000
Private Utilities	4,308,768	20,523,808	1,870,000	226,000
Industrial	5,301,051	32,792,556		
Total	42,629,725	204,722,897	15,966,000	2,200,000

*Figures for fixed assets for generation and transmission facilities of industrial establishments are not available.

THE URANIUM INDUSTRY

In the Canadian uranium industry, one of the most closely controlled industries in Canada, there exists a considerable degree of state participation by the federal government.

In 1944, the government expropriated all private uranium operations, and from then until 1958, held a monopoly position in uranium procurement through a Crown corporation, Eldorado Mining and Refining Ltd. In 1947, private companies were permitted back into the exploration and mining fields, but it was not until 1959 that they were allowed to enter into sales agreements with anyone other than Eldorado.

Today, the Government of Canada participates in all phases of the nuclear industry. Eldorado (now called Eldorado Nuclear Ltd.) possesses one of the three uranium mines operating at present and also owns the only facility in Canada capable of upgrading U_3O_8 to the more refined level of UF_6. In addition, the government moved in 1971 to establish the Crown corporation, Uranium Canada Ltd. (UCAN) to participate in a joint-venture stockpiling arrangement with Denison Mines Ltd., thereby ensuring continuity of operations at their Elliot Lake mine. UCAN has the added responsibility of arranging for the sale of $100 million worth of uranium previously stockpiled by the government in its program of assistance to this industry during the period of depressed markets.

THE NUCLEAR INDUSTRY

The successful realization of the Canadian nuclear generation program in the form of the CANDU reactor is an important contribution to Canadian sovereignty and independence as the result of state participation by the Govern-

ment of Canada in this critical area of technology. The nuclear fuel industry, the heavy water industry, the supply of the nuclear portion of the CANDU system and the electrical generating facilities are entirely within the technical and industrial capability of Canada.

The major industrialized countries of Europe, the United States and Japan have committed themselves to the use of U.S. technology in the form of light water moderated nuclear generating capability, using enriched uranium. The enrichment process for uranium, in terms of the supply of that material to commercial nuclear power reactors, is presently a monopoly of the U.S. Government-controlled Atomic Energy Commission. Thus, in their nuclear generating program, the key competitors of the United States in the world economy, the European Economic Community and Japan, are heavily dependent on the United States for the growth of their nuclear electrical power generation systems.

The research and technology for the CANDU system was developed by Atomic Energy of Canada Limited, a Crown corporation owned by the Government of Canada, which is charged with a variety of responsibilities for the development of peaceful uses of atomic energy. The user experience, the knowledge of the requirements of an operational generating system, and the detailed knowledge of the capabilities of equipment for the generation of electrical energy from the CANDU reactor heat source were the contribution of Ontario Hydro, a provincial/municipal "state-owned" agency.

Clearly, the role of state participation on the nuclear side of the Canadian energy scene is and will remain important. It is estimated that by the year 2000, 44 per cent of the total electricity generated in Canada will be generated by nuclear energy as compared to 2.8 per cent in 1972. Relatively speaking, it is expected that because of the growth in the use of nuclear energy, governments will play an even more substantial role in the electrical energy business by the early years of the next century.

The Coal Industry

The role of coal as a source of primary energy in Canada is not large. In 1970, the percentage of total energy derived from coal was 11 per cent. In the year 2000, the percentage is estimated to be 8 per cent; the least significant of the major forms of energy. While in relative terms the coal industry is not expected to grow as a source of energy, nonetheless, in absolute terms, very substantial amounts of new investment can be expected in developing Canada's coal resources.

As against economically recoverable reserves of at least 2 billion tons, Canada has a coal reserve potential of 120 billion tons. Given a reasonable growth in world prices for coal, it can be expected that significant developments in this industry will occur, both to serve the energy industries and the metallurgical coal markets.

Nearly all of the Canadian coal industry is in private investment hands—foreign investors control 73 per cent of the coal mining now being conducted in Canada. It has been calculated that this percentage will likely grow somewhat over the coming years as the result of the concentration of the industry into the hands of the large corporations which can meet the financial and technical challenges.

Is there a role for enhanced state participation in the Canadian coal industry? The federal government has already intervened to become the owner of the coal mining operations on Cape Breton Island in Nova Scotia. (The steel mill at Sydney, which is supported by Cape Breton coal, is owned by the Province of Nova Scotia.) It is not expected that the Cape Breton coal mines will become a viable commercial operation during the next decade, nor was the reason for federal investment a commercial one. Federal participation in this instance was brought about by social objectives relating to the maintenance of an established community of Canadians and by longer term intentions to diversify and develop the economy of the Cape Breton region.

Large coal reserves remain to be developed in Western Canada, primarily in British Columbia and Alberta, but with some important potential also in Saskatchewan. A new measure of state participation in the coal industry in British Columbia was recently indicated when the Premier of that province, through the agency of the B.C. Railway, announced intentions to acquire a 40 per cent interest in the Sukunka coal property, which is a deposit of high-grade metallurgical coking coal. The Government of the Province of Saskatchewan holds substantial deposits of lignite coal which it may well wish to develop either entirely by a provincial agency or by some other form of state participation, possibly in partnership with private interests.

The federal government is the holder of important coal deposits in the East Kootenay area of British Columbia in what is known as the "Dominion Coal Block". It has been calculated that a commercially successful metallurgical coking coal operation could be brought into production from these deposits. The only market for such coal which can be immediately foreseen would be an export market, although potential market possibilities do exist in Ontario given certain economic conditions. It can be asked whether the federal government should seek to develop these deposits by some method of direct state participation, or whether it should assign their development to the private sector, because of their minimal relative importance to the overall Canadian energy scene. Some argue that state participation is necessary in order to provide the federal government with detailed working insights into the operation of the coal industry, bearing in mind the enormous growth potential for Canada's coal export trade, as well as the possibilities of long-term growth in the domestic consumption of coal. With the increased awareness among Canadians concerning domestic control and ownership over Canada's mineral resources, it is possible that there may be some support for direct state participation in the eventual development of the Dominion Coal Block. On the other hand, if the only ready market for coal is the export market, there may be justification to question the use of public monies for such an endeavour.

The Oil and Gas Industry

The capital investment of the oil and gas industry in the resource sector amounted to some $14.8 billion up to 1971, or some 47 per cent of the energy industries. While the role of this industry, including oil and natural gas and associated products, will decline slightly relative to the electrical utility industry by the year 2000, it will nevertheless grow substantially in absolute terms and will

be a very prominent industry in the Canadian economy over the next several decades.

It is estimated that a substantial percentage of the Canadian petroleum resource base remains to be explored for, discovered and developed. As against remaining proven reserves of 9.7 billion barrels of oil and 52.9 trillion cubic feet of gas, it is felt that there exists in Canada potential recoverable resources of more than 400 billion barrels of oil (including oil sands and heavy oils) and more than 700 trillion cubic feet of gas. Given a strong demand for oil and natural gas, both in Canada and elsewhere, for the remainder of this century and well into the next, and given reasonable growth in world prices for energy, it appears likely that most of the growth in the Canadian petroleum industry remains ahead of us.

Nearly all of the Canadian petroleum industry is in private hands. The state-held investment in the Canadian petroleum industry amounts to less than one per cent of the privately-held investment and is based largely upon the federal government's participation in Panarctic Oils Ltd.* (45 per cent of the ownership of that company), and the Province of Quebec's 100-per-cent investment in Quebec Petroleum Operations Company (SOQUIP). Examples in the gas industry are the activities of the British Columbia Hydro and Power Authority and Saskatchewan Power Corporation.

All of the integrated petroleum companies operating in Canada (companies which explore for, develop, produce, transport, refine and market oil and petroleum products) are foreign-owned and controlled. In 1970, these companies accounted for some 95 per cent of all sales of petroleum products in Canada, as opposed to only 5 per cent for the Canadian-controlled companies. However, nearly all of the natural gas distributed and sold in Canada is controlled by Canadian-controlled companies.

Is it a matter of concern to the people of Canada that an important segment of the Canadian economy, the petroleum industry, is foreign-controlled or that it is almost entirely private-sector controlled as opposed to a significant degree of state participation? What are the cases for and against state participation in this industry?

There are many related questions in trying to grapple with this issue. For example, why has state participation in the generation of electrical energy been so important to Canadians up to this time, while the discovery, development and utilization of Canada's petroleum resources has apparently not required any important form of state participation? Is the difference in risk between the two industries a feature of importance to this question?

Many other countries have become involved in one or more phases of the petroleum industry, for a variety of reasons. Are their reasons and experiences rele-

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*Panarctic Oils Ltd. is not a Crown corporation. Essentially, it is a company whose shares are held by the federal government and more than twenty other investor groups. The federal government's share interest is approximately 45 per cent of the common equity stock. The balance of the investors, almost all of whom are Canadian-controlled companies, hold 55 per cent of the common equity stock. The majority of Directors of Panarctic have been elected by the shareholders from the business sector.

vant to the Canadian situation? Examples of state participation in the petroleum industry are described in Appendix B of this report. Suffice it to say here that it is evident that there is no uniformity of reason and no uniformity of historical experience why these countries, and others, entered into some role for the state in their petroleum industry. The entry into state participation seemed an answer to a particular need within the national community—whether economic, social or political. To a surprising degree, the reasons in most countries were not significantly economic, but related more to factors of direct concern to the state—security of supply, the role of the foreign participant in the domestic economy and its impact on the management and growth of the economy. In some cases the reason was simply the desire to use the petroleum industry as a symbol of what a country could do on its own to increase the pride of its people in national accomplishments.

Section V of this report discusses the degree and ramifications of foreign control of the Canadian energy industries. In the chapter dealing with the impact of foreign control, it is observed that one of the principal questions concerning foreign control of the energy industries is whether we are getting the optimal benefits from exploitation of our energy resources. Does the high level of foreign ownership and control of energy resources in Canada reduce the realization of benefits in Canada? Does this level of foreign participation make the realization of Canadian objectives for resource development more difficult? Does this level of foreign participation alter or limit in any way the variety of government techniques which might be appropriate to the realization of our objectives?

In summary, is there a particular problem in Canada at this point of time in the petroleum sector, the solution to which may lie in part through augmented state participation? If there is a problem, to what extent is it economic and to what extent does it lie in the social and political aspirations of Canadian society? To those who feel that enhanced state participation in the petroleum sector is desirable in Canada, the inarticulate premise of their conviction may be as simple as a desire for Canadians to do their own thing in their own way. Those who have economic arguments do not normally base them on any specific inadequacy in the performance of the privately held petroleum industry in Canada. In fact, on both sides of the debate, many would argue that the record of private industry in exploration and development has been good. However, out of an appreciation of the opportunities for growth anticipated in the next ten or fifteen years in the Canadian petroleum sector, they have a bias in favour of Canadian control, so as to ensure that a greater amount of the economic power in the growth of this industry goes to Canadians and provides a better balance within the industry between Canadian and foreign-controlled activity. Those who argue that the state must intervene in order to achieve this better balance, also argue that the Canadian private sector is not and cannot be made sufficiently strong to organize and carry out the major effort in achieving the growth of the Canadian petroleum resource base within the relatively few years which remain. Efforts could be made to encourage the Canadian private sector but these would tend to introduce inequities.

Those who support state participation in the petroleum sector do so with a variety of arguments which seem to be grouped around the desire to increase

Canadian control. One method designed to provide greater Canadian participation and ownership in the petroleum industry is the establishment of a national petroleum company (NPC). Proponents of an NPC suggest that it could be a flexible policy vehicle designed to achieve the realization of some of the objectives for Canadian energy resource development. In the succeeding pages, the advantages and disadvantages of such a course are discussed.

Just what is meant by a "national petroleum company"? Obviously, an NPC could be established to concentrate in only one or two areas of the multi-faceted petroleum industry. For the purposes of the ensuing discussion, however, the scope of the NPC proposed is that of a fully-integrated petroleum company operating in the exploration, production, transporting, refining and marketing spheres of the oil industry, on a nation-wide basis.

Why create a national petroleum company? *What benefits are anticipated which would accrue to Canadians?*

1) Perhaps the greatest advantage of an NPC is the social benefit to Canadians of the pride, satisfaction and confidence of owning a portion of the petroleum industry operating in Canada. It is a benefit which cannot be quantified, but if Canadians are concerned that the domestic petroleum industry is foreign-controlled, then an NPC would help to ease that concern. Social satisfaction would accrue from the expectations that ultimately Canada would reap more of the profits associated with successful petroleum industry operations.

2) There is a need to increase the level of knowledge of all phases of the operations of the petroleum industry. While Canadian-controlled companies in the private sector are active in some spheres of petroleum industry operations, only a few foreign-controlled fully integrated companies have the broad knowledge and experience associated with the total spectrum of the petroleum industry. An NPC of important size would have, as one of its key objectives, the increase of Canadian knowledge about the domestic and international petroleum industry. It would be concerned about the Canadian resource base, the problems of exploration, development and transmission, marketing, transfer prices, and all of the aspects of the commercial activity which interrelate so much with the role of public policy. However, it might be agreed that acquiring such knowledge and insights will be neither easy nor inexpensive.

3) An NPC could play some role in determining the criteria on which the government might base its policies regarding economic rent collection. Unless it were a corporation of immense size, relative to the total petroleum sector, the NPC obviously would not be a significant direct agent for the government in the collection of economic rent. However, an NPC could play an important role in establishing a reasonable value by which rent would be determined; for example, when Crown lands were being offered for bonus bids. This benefit cannot be completely divorced from the previous one regarding the improvement of knowledge of the activities of the petroleum industry. Economic rent is obtained in part by the government by taxes, royalties and similar measures. Corporate taxes, based on profit, can to some extent be controlled by foreign-owned companies if the parent corporations levy relatively heavy charges on Canadian subsidies for management services, patent fees, and other business transactions. The NPC, being

independent of a "parent" company, would provide information on its integrated operations by which other privately controlled companies could be gauged, information which would provide the government with guidance on how best to collect economic rent.

4) An NPC, if it controlled sufficiently large volumes of petroleum reserves, would be able to exert an influence on the setting of crude oil and product prices. Crude oil prices, or the posted wellhead prices, are set at present by the "majors", and on the main the posted prices are tied to the Chicago market price. An NPC would be independent of this situation and could set prices appropriate to Canadian conditions.

5) Export demand for Canadian petroleum has been predominantly for crude oil and other unprocessed feedstocks. In 1971, 95 per cent of Canadian petroleum exports were crude oil and equivalents. An NPC could encourage the upgrading of crude oil in Canada by seeking an export market for refined products rather than for the unprocessed raw petroleum, with greater attendant benefits to Canada in value added, employment, and other effects.

6) The major integrated oil companies carry out the bulk of their research in the country of their parent corporations. Little real petroleum research is done in Canada compared to the importance of this activity to the Canadian energy scene. An NPC could act as a centre for Canadian research and development, concentrating particularly on unique Canadian opportunities and on the potential for spin-offs in industrial activity and technology to Canadian industries. Of course, the same kind of research and development could be conducted by the government, or indirectly by funding of a research institute. The advantage of an NPC having such research and development as a major objective would be that it would likely have an immediate opportunity for field testing and for commercial application which would probably not be available to the government or an institute. On the basis of such research, the NPC would also have the advantage of developing contacts with the Canadian manufacturing industry which might increase Canadian content in petroleum developments.

7) Because all aspects of the operations of the NPC would be resident in Canada, increased employment benefits, relative to the foreign-controlled corporations, could accrue to Canada. In addition to the establishment of the company's head office and the need for field staffs, employment benefits should be realized in the supporting service and supply sectors.

8) An NPC should purchase to a greater extent than the foreign-controlled companies Canadian produced goods and services. Existing Canadian technical and administrative service and supply establishments would have both the incentive and impetus to expand, which would give this sector a firm basis upon which to grow and, hopefully, develop into a world scale services industry in its own right. Indeed, Canada could develop a leadership position, given appropriate incentives, in specialized areas where the industry can demonstrate pathfinder techniques—particularly in offshore, high Arctic and oil sands technologies.

9) An NPC could act to stimulate regional development in specific areas of the country. There are many areas in Canada with petroleum potential which, for a

variety of reasons, are not attractive to the private corporation. The geology may not be as favourable as their prospects elsewhere in Canada or outside of Canada. Labour productivity may be a problem or there may be a lack of competitive transportation. It might prove entirely impossible for a government to provide, by legislation, special incentives to encourage the private sector to work in designated regions in Canada. The tax system may be unavailable for special incentives because of the desire to have rules of equal application throughout Canada. At times, circumstances may make legislative or regulatory activity undesirable to a government to encourage the private sector to step in by changing the odds in comparison with other opportunities for the investment of capital and the use of risk money. An NPC could be an important vehicle for mineral activity in these relatively unattractive regions. These could include the west coast of British Columbia, certain parts of the B.C. interior, areas in the Gulf of St. Lawrence and both offshore and onshore in the Maritime Provinces. Additionally, more work might be done on Hudson Bay and in southern parts of the Northwest Territories.

If it should occur that only marginal petroleum fields are discovered in a certain region of Canada, such marginal fields might not be attractive for development by the private sector. Nonetheless, for political and social, rather than purely economic reasons, the government could well regard such development as important to the region and perhaps even to Canada as a whole. This area of activity, while justifiable for an NPC, would not be appropriate to a private sector company which must assess possible development on a strictly commercial basis and which would expect a higher rate of return than might be acceptable to an NPC and to the government.

Basic to this argument is the concept that a less than optimum economic oil and gas development program would be encouraged. This is one spectre of the operations of an NPC that would need to be weighed carefully, if it is also to be a goal for the company to operate in a relatively economic fashion.

10) An NPC might also play an effective role in government relations with other countries where their state companies were dominant or active. In the OPEC countries, government ownership of the majority of production and development activity is proceeding rapidly. Also, there is a trend towards more OPEC-government participation in refining and marketing. Many of the leading consumer countries also have state corporations and it is possible that by the early 1980's an important share of the international petroleum trade will take place through government-to-government arrangements. Canada may find it advantageous to have a national vehicle for this purpose in order to participate in international oil trade. In any event, an NPC could create a channel for oil deliveries to or from Canada, outside of that provided by the major oil companies. This more balanced distribution may enhance Canadian security of supply. A possible additional benefit may relate to the achievement of some effective trade arrangements with major oil-producing nations: for example, Canadian oil purchases in exchange for the sale by Canada of goods and services, not necessarily related to oil.

On the other hand, the interjection of an NPC in international petroleum affairs will tend to reduce the role of the major international companies, thus a buffer between the government and the producing states would be set aside. There

would be no doubt that the activities of the NPC would reflect government policy. Should such activities result in difficulties, these difficulties would clearly be between governments and not just with the operations and negotiations of the oil companies.

It can be seen, therefore, that there are a number of social, economic, and political arguments in favour of the creation of a national petroleum company. The list above is not an exhaustive one. Despite the apparent advantages to Canada accruing from an NPC, none exists today. Why? *What are some of the factors which militate against the creation of an NPC?*

1) Probably more than any other factor, the question of cost inhibits the creation of an NPC. To start from the beginning—to assemble acreage, find oil, build pipelines, refineries, and marketing facilities—the cost would be extremely high. Judging from the investments in national petroleum companies in other countries, the cost could fall in the range of $3-6 billion. A portion of this cost, to be borne by the Canadian taxpayer, could be over and above the approximately $50 billion needed to finance major energy projects during the next decade.

The creation of a large, integrated petroleum company is not an easy task and one could reasonably assume, even given a high degree of success in exploration and market penetration, that it could take 15 to 20 years for the company to be a significant force in the industry.

2) The world enters an era towards the end of this century when the petroleum industry will experience a slower rate of growth. Most of the large, integrated oil companies are already diversifying into other areas such as chemicals, hotels, and coal and uranium mining. Given this situation, it may be unreasonable to expect that a publicly-owned company could gain a substantial share of the market against competition from the multi-national firms and also achieve a reasonable growth rate strictly within the petroleum industry.

3) Should Canadians determine that the benefits of an NPC outweigh the high cost, there are major barriers to the creation of a national oil company. In the first place, it would be time consuming and/or expensive for an NPC to assemble substantial potential oil and gas acreage. Most of the territory expected to yield new oil and gas reserves is already under permit to petroleum companies. If restricted to frontier areas, the NPC therefore would be forced to search for and produce oil from high cost areas, at an economic disadvantage to the other integrated companies. Land might be acquired by an NPC through access to the government's Crown Reserves and the government's share in Panarctic holdings.

If the NPC were to seek and obtain acreage in the western provinces, the cost would be relatively high, given today's high petroleum prices and anticipated higher prices of tomorrow. Additionally, it is conceivable that the NPC, owned by the federal government, could be the cause of some federal-provincial conflicts concerning resources development policies.

In addition to envisaged difficulties associated with the assembly of potential oil and gas acreage, should the NPC be established and superimposed over the existing petroleum industry framework in Canada, surplus refinery capacity might be created. If this surplus were to be used to process crude in Canada to provide

petroleum products for the export market, market disruption in Canada would be minimal. However, if a major surplus of product were allowed to develop in Canada, it is possible that the resulting competition could be damaging to the industry, although to the possible advantage of the consumer in the short run.

The marketing activities of the integrated petroleum companies have, to date, been only marginally profitable, the major portion of profits being realized in other areas of their operations. If this situation continues the imposition of a major new marketing endeavour by an NPC could have serious disruptive effects on the retail end of the industry, particularly if it occurred during a period of surplus petroleum products. In this case the NPC might be forced to cut prices in order to gain a market share. Indeed, short of outright purchase of retail outlets, it may be difficult for the NPC to establish a successful retail marketing operation. Most if not all desirable locations for retail outlets in urban areas are already in the hands of the existing companies, and many urban centres, faced with an overabundance of retail petroleum outlets, have passed laws restricting additional growth. Is there, therefore, a market potential for an NPC?

Some of these difficulties might be overcome to a degree if, rather than creating a new company from the beginning, a state oil company were created by purchasing outright one of the Canadian subsidiaries of the foreign-owned integrated oil companies. The cost of buying the total assets, including capital facilities, acreage, goodwill, etc. could be excessive. Strictly as an example, Imperial Oil, Canada's largest oil company, in its 1972 Annual Report, reported shareholders' equity of $1.12 billion, and gross proved reserves of 1.4 billion barrels of oil and 3 trillion cubic feet of gas. Issued capital stock at the end of 1972 totalled 129,520,215 shares. At an average market price of $40 per share (1972 stock prices ranged between $30 and $50 per share), it would cost at least $5.2 billion to purchase Imperial Oil. However, to buy any existing foreign-owned company presupposes that the owners would be disposed to sell, an hypothesis which is debatable.

4) Sixty-six per cent of petroleum company capital needs in Canada are derived from the internal sources of the companies. The multi-national corporations have permitted their Canadian subsidiaries to retain much of their earnings in Canada to finance exploration and expansion programs. It is conceivable, given evidence of a relatively hostile climate in Canada, whether real or imagined, but spearheaded by the creation of an NPC, that foreign shareholders of the Canadian subsidiaries may call for a greater repatriation of profits on their investments. Thus, the creation of a large, competitive NPC might discourage the multi-national corporations from continuing to reinvest their earnings in Canada, with undesirable economic consequences.

5) Due to the diversity of its goals, the NPC is likely to be less commercially efficient than its competitors, and therefore not effective in playing a major role in maintaining or setting low prices. Additionally, should the NPC be less efficient than its competitors, it might prove to be a poor yardstick by which the government could judge the economic rent collection prospects of the more efficient members of the industry.

6) As stated in the introduction, the overall record of private industry in the exploration and development of petroleum in Canada has been good. Foreign-controlled companies have provided leadership and have been prepared to accept the substantial risk associated with exploration in difficult regions of Canada. One must ask whether an NPC could operate free from political and public pressure in the face of continued unsuccessful exploration programs. For example, would the Canadian public stoically accept the prolonged lack of success which has dogged exploration programs off the east coast during recent years.

Certainly some aspects of the company's operations would be governed by social or political decisions rather than economic criteria, but one must also question whether the NPC would be allowed to make important investment or capital decisions based on purely market factors. For example, would the NPC be forced to build refineries in depressed areas? Would there be a conflict between regional interests for the location of refineries?

7) The NPC might attain a dominant role in terms of the policies and regulations relevant to the petroleum industry. This dominant role would come about through the expertise the company's officers would develop within the company. Senior officials could lay claim to having knowledge of "what was best" for the company and Canada, rather than government officials in regulatory and policy making positions. In such a situation, conflict could occur, and the objectivity essential to the successful formulation of policy and implementation of regulations could be jeopardized.

8) The assumption that an NPC would achieve public acceptance at the retail sales end presupposes that Canadians would prefer to "buy Canadian". There is no evidence to support this proposition, and indeed, past experience with such companies as "White Rose" and "Supertest" suggests that Canadians did not rate "Canadian content" high in their decisions to frequent specific petroleum companies.

The comments just outlined do not constitute an exhaustive list of arguments for or against a national petroleum company. Clearly, many of the policy issues could be achieved by a variety of alternate means—either with legislative, fiscal and regulatory support, or simply by the enunciation of government policy in specific sectors. It is not the purpose of this paper to make value judgements on the merits of the creation of a national petroleum company; however, the public should be aware of the major benefits, costs and associated risks involved in such a venture.

Summary

In review it is clear that provincial government participation in the Canadian electrical utility sector is firmly established, and that this sector of the energy industry will continue to grow in importance. The federal government is active in all aspects of the uranium and nuclear industries, and to some extent in the coal industry. Indeed, the federal government has a considerable number of diversified existing interests in various sectors of the energy industry. Present federal holdings or rights are:

(1) Eldorado Nuclear Ltd.
(2) Panarctic Oils Ltd.
(3) Northern Canada Power Commission
(4) Atomic Energy of Canada Ltd.
(5) Uranium Canada Ltd.
(6) Crown reserves on federal lands
(7) Rights to federal government oil and gas royalties in kind
(8) Dominion Coal Blocks
(9) Nelson River High Voltage Transmission Line

Conceivably, the federal government might enter into several other areas of energy activity, such as:

(1) Federal role in a trans-Canada electrical grid development
(2) Federal role in deep-water oil terminals
(3) Purchaser of oil and gas and pipeline interests
(4) Energy research and development
(5) Marketing boards for international purchase or sale of crude oil or petroleum products.

The time is shortening for government to decide whether there are reasons of public policy for either some additional participation, or quantum change in participation, in the development of the energy sectors of Canada. It is clear that enormous growth will take place in all aspects of the energy sector. Are additional public funds required to assist in the channelling of this growth, in its stimulation, in its sensitivity to environmental and social issues, to counteract foreign investment, for international relations purposes and for many other issues of public concern? Must any decision by government to participate be based solely on economic criteria or should government become involved for reasons relating to the development of the Canadian political community, accepting commercial returns of a lower scale?

Have we reached a situation in Canada where it is desirable, within the energy sector, to make a specific advance in national development rather than simply to generate a profit? Presumably, such state participation companies as Canadian National Railways, Air Canada, Telesat, Eldorado Nuclear and Panarctic are vehicles for state participation where the government's goals are not primarily profit oriented. On the other hand, the Government of Canada has also, at this time, a 100 per cent interest in the shares of the Canada Development Corporation, and one of the goals of the CDC is to produce a net return on investment of 15 per cent per annum. If the government wishes the CDC to serve from time to time as an agent of public policy, then the government must contribute to CDC directly the costs of such public policy involvement. This is an understandable commercial attitude in circumstances where Canadian citizens may soon be invited to be shareholders in CDC. The duty of a public corporation is, indeed, to protect the interests of all of its shareholders in the carriage of its commercial business.

In the event that it is concluded that requirements other than profitability considerations should play a significant role in the development of the future Canadian energy sector, for reasons such as regional development, Canadian control, security of supply, special environmental and social programs and so on,

then consideration will have to be given to the organization of new institutional forms. A variety of choices would be open to government. In addition to consideration of further possible government participation in selected sectors—such as, for example, direct participation in the oil industry—another option open is the creation of an energy holding company which could coordinate all the varied energy sector activities of the federal government, and serve as a vehicle for further government participation in selected areas. Such a corporation would act as a pace-setter in the development of the Canadian energy sector and in competition with privately-owned elements. Its management would require all of the training of the private sector and, at the same time, would have to have the capability of bridging between the commercial sector and government in order to carry out the broad public policy responsibilities which would be the justification for the corporation. Long-term policy goals and guidelines would have to be clearly articulated.

SECTION IV

ECONOMIC IMPLICATIONS OF ENERGY DEVELOPMENT

INTRODUCTION

This study was carried out in the Department of Energy, Mines and Resources. It includes assumptions about variables relating to macro-economic policies which are not intended to predict future economic strategies but simply to illustrate the direction of economic forces resulting from certain hypothetical conditions.

The main purpose of this section is to estimate the capital requirements of five energy development scenarios, and to measure the kind of economic impact those investment programs might have. Four of the scenarios reflect varying degrees of exports associated with projected supply conditions of Canadian energy resources, while the fifth describes a self-sufficiency case. The section also endeavours to discuss the major concerns and questions which Canadians would have to answer before deciding whether to divert scarce resources into energy development. No attempt is made, however, to quantify the longer-term costs and benefits from such development. Studies are under way to find more definitive answers to these problems.

The report also looks back at the past performance of the Canadian economy relative to the resources boom of the late fifties with a view to complement the results of quantitative studies with past experience.

The impression of precision which quantitative studies tend to create, should not be construed as projections of future events or a forecast of the economic setting of the seventies. They represent the first results of the studies conducted and their only purpose is to provide a bench-mark against which relative changes and performances can be measured to assess the approximate magnitude and direction of the economic forces brought into action.

Chapter 1

SOME CONCEPTUAL ISSUES OF ENERGY DEVELOPMENT

A discussion of economic implications of energy development must balance quantitative and qualitative study. The economic impact of possible investment programs when considered in the framework of some of the broader conceptual issues allows for a clearer perspective of the overall economic implications. Such an approach emphasizes the fact that econometric studies do not necessarily provide definitive answers to all the questions that may be asked.

The formulation of energy policies must encompass the interrelationship of economic issues with the nation's social concerns. It must consider questions relating to economic issues such as the effects of energy investment on income, employment, economic welfare, balance of payments and productivity, as well as the social problems which include security of supply, environment, social welfare, international relations, and foreign ownership. Even if the answers to these questions can be found, a further process is involved with respect to the timing of developments, the directional pressures to be imposed by government and the nature of the government's participation through ownership, regulation and rent collection.

Given that the answers to these questions must be forthcoming in the final analysis, a consideration of the economic impact of the investment phase of various energy development scenarios can provide valuable insight into the problems that must be considered in the future. The total capital requirements of possible resource projects and the ability of the economy to facilitate them can be measured. An understanding of the impact of large investments on prices, exchange rates and other economic concerns represents a starting point for the further study required into the operational phase of development, the longer-term implications and the related socio-economic issues, including the important regional implications.

As discussed in other sections of this report, the expected severe energy shortage in the United States through to the mid-1980's and the prospect of a continuation of the recent high rates of price advance for petroleum products from OPEC countries, suggest a strong external demand for Canadian energy into the 1980's. The study of Canada's future energy supply and demand conditions has also concluded that Canadian reserves of relatively cheap energy are expected to decline in this decade; that Canadian energy resource development in the future will reflect the need to bring on stream increasingly costly frontier resources; and finally that the availability of higher cost Canadian reserves could be more than sufficient to meet Canadian energy needs in the foreseeable future if producers are allowed to respond to probable future market conditions. Therefore, this economic viability study is based on the premise that world market conditions may induce considerably larger Canadian energy resource development in the

1970's than indicated by projection of historical trends and that any energy surplus can be marketed abroad. The energy development cases discussed in this study are illustrative and reflect the Canadian economy's response to different investment programs, most of which are associated with varying levels of energy exports.

This chapter attempts to discuss some of the major concerns and issues of energy development; it raises relevant questions of benefits to be derived from energy development; and it discusses the problems related to the economic impact of the investment phase.

THE ECONOMIC ISSUES OF ENERGY DEVELOPMENT IN CANADA

There are differing views of the benefits derived by Canadians from resource development in the past. On balance, however, there is evidence that economic and social gains accrued from development of Canada's energy resources to the present position of self-sufficiency; although people may differ on the question of whether such benefits could not have been higher by pursuing different policies.

The potential economic and social gains from future resource development may be markedly different from that of the past. This reflects not only the evolving structure of the Canadian economy, but also the changing priorities of our society and consequently, the requirements of industrial development. It is no doubt true that the development of our natural resources helped Canadians to attain one of the highest standards of living in the world and also an advanced level of industrialization. Further emphasis on the exploitation of non-renewable resources may, however, be detrimental to the achievement of the longer-term socio-economic goals.

The focus of this discussion of the economic issues of energy development in the 1970's is somewhat limited in that it does not deal with the more intangible factors, encompassing the spiritual, cultural, environmental and other aspects of our quality of life. This is not to deny that such intangibles are related to economic activities and are important to governments in formulating industrial policy. Rather, this approach recognizes the limited ability of economic analysis to provide answers to the overall questions.

The central economic issue of energy development is to what extent, and under what terms and conditions, should the development of Canada's energy resources be allowed to respond to industry expectations of greatly enlarged U.S. markets for Canadian energy at rapidly increasing prices over the next decades.

A number of very large and ambitious energy development projects are now under active consideration by both domestic and multinational corporations. Such projects would involve development of natural gas, oil and other energy resources in Canada's Arctic and offshore. Many would be undertaken primarily to service prospective U.S. markets.

That such schemes may be profitable to private investors does not necessarily mean that the welfare of Canada and Canadians would be enhanced if they go forward as presently conceived. In point, such projects will absorb the country's scarce factors of production which could be used for development in other sectors of the economy. A crucial factor to be considered in evaluating the different investment proposals in the energy sector, or for that matter in any other sector, is the

income generated by the investment over the longer term and the extent to which this income accrues to Canadians. An associated problem is the adjustment process and the costs to move resources into and out of different economic activities.

To interpret the potential profitability of investment projects to their private owners as an indication of their social benefits to Canadians is rather intrepid for most investments but particularly so for the energy sector. The most extreme example is the oil and gas industry which is dominated by oligopolistic, multinational corporations. Investment decisions by such corporations are influenced not only by their advantageous market position and the high risk nature of the business, but also by the rules and regulations laid down by provincial and federal governments to govern and participate in their operation. The present modus operandi was probably justified in the past when the emphasis of government policy was directed toward the attainment of self-sufficiency in petroleum production even though Canadian reserves were relatively high cost. As related in the chapter on economic rent, such terms may be generous in view of the present international environment of supply shortages and escalating demand for oil, gas and other forms of energy. Such advantages go beyond the taxation and royalty provisions but also cover the traditional arrangements whereby governments and ultimately the taxpayer pay for some of the external costs of resource development such as public transportation facilities and protection of the environment.

It is difficult to quantify the importance of this industry structure and such development incentives on the profitability of oil and gas investments, or to compare these factors with the incentive packages open to other more competitive industries. The more interesting question is the extent to which presently planned oil and gas developments would be postponed or diverted to other countries if such projects, in addition to the economic rent, had to shoulder a greater share of the external costs. At the same time, the benefits to Canada from the depletion of our non-renewable hydrocarbon reserves may be limited if the potentially high profits from such developments accrue in large part to non-residents and not to Canadians.

The prospect of an enlargement of the energy sector in the 1970's has led to a further concern regarding the foreign ownership and control of a large number of the proposed projects. In addition, that the viability of specific projects requires large foreign capital inflows and export markets, is argued as being justification for resisting accelerated energy development. The validity of the related arguments appears to rest primarily on social, political and/or income distribution factors. Such factors are important but the economic arguments used to marshall support for them are often focused on short-term consequences only. As discussed in the chapters on foreign ownership, the important economic issues are the terms and conditions under which energy development, and for that matter any other foreign investment, proceeds. The use of foreign resources for industrial development can provide important benefits if it takes place under proper conditions. Any nation that rejects foreign trade and foreign investment under reasonable terms and conditions, would deprive its citizens of important benefits. This is particularly true for Canada with its abundance of primary resources and its heavy dependence on foreign trade.

Even if a satisfactory arrangement can be made between industry, government and the consumer on the income distribution issues, the government will have to deal with the important question of the pace of resource exploitation. Essentially the answer to this question hinges on the benefits to Canadians from exploitation of our energy resources "now or later." An important consideration is whether or not it is more advantageous to exploit and export resources now, thereby generating income and employment for the present generation, or should the country speculate and defer for future generations, income that would be currently available. An additional factor is the physical availability of energy and the possible need to gear the pace of development exclusively to the growth in domestic energy demand. The latter is in the forefront of the concerns of many citizens and it influences the thinking of many prominent scientists.

It is pointed out that the estimates of Canadian energy resources suggest a resource base which, although adequate for our own foreseeable requirements, represents no more than a few years of the United States' vastly accelerating needs. It is argued that the exhaustible supplies of fossil fuels have special highly desirable characteristics with few possible substitutes. If there is no major technical breakthroughs and if Canada allows an indiscriminate exploitation of our reserves to feed U.S. needs, then this country would soon be in a similar position to that of the United States.

The possible dependence on volatile and insecure foreign sources of supply leads to the conclusion that we should husband our energy resources for domestic needs. A related argument is that with few possible substitutes for hydrocarbons, a burgeoning demand for clean energy and the increasing power of OPEC countries, the price increases for petroleum products will be so great as to justify postponement of Canadian development even with a time discount factor.

Accepting that the present policy of allowing hydrocarbon exports only in excess of foreseeable domestic requirements will continue, the "now or later" question rests essentially on the interconnection between international scarcity of supply, future price development, and the advance of energy technology. To speculate about scientific developments is even less rewarding than evaluating the longer run economic implications of energy development. Over a limited time horizon, technological breakthroughs cannot be counted upon to provide economically competitive substitutes for hydrocarbons on schedule. Although, as a longer-term proposition, our past experience suggests that there will be such breakthroughs.

An important consideration to Canada is that with or without our exports, the United States is determined, for security of supply reasons, to find a solution to their present energy crisis. It is possible that in 15 to 20 years, some of Canada's more costly frontier resources may be excluded from export markets if the United States and other major consuming nations are successful in resolving their energy crisis from either new domestic sources or major technological breakthroughs. This would not only limit income generation in these Canadian industries and decrease our foreign exchange earnings, but it might also force Canadians to absorb a greater proportion of the costs involved in providing access to frontier resources.

As to future price developments, the increase in prices would have to boost income well above the expected growth in costs and the benefits derived

from the spin-offs of the re-spending of current income. Although this answer is contingent on a wide number of factors, policy should be based on wider support than an uncertain price outlook. This is particularly relevant in light of the potential benefits to be foregone from locking in reserves.

The longer-term economic issues relating to the desirable pace of energy development centre on whether the long-term income stream derived from energy investment is in fact higher than that income which could be generated by leaving the required capital resources where they are presently employed and/or by placing them in alternatively proposed projects.

Many Canadians argue that the economic environment should be changed in order to create a climate which would induce faster growth in certain sectors of the economy and serve to retard resource development in general. Support for this position is normally based on either of two premises. The first is that the oligopolistic nature of certain energy industries and particular development incentives allow such industries to attract and hold more factors of production than their true profit position would warrant. This in turn is held to limit the growth opportunities of sectors with higher productivity and thereby retard the growth in national income. Often this premise is expressed in relation to the impact on the competitive position of Canada's manufacturing industry from upward pressures on the exchange rate associated with the foreign financing of resource development and export of primary products. A second premise, sometimes related to the first, gives more weight to the employment objective. It is argued that Canada's secular employment problem requires industrial development which is more labour intensive even if some sacrifice in the rate of growth in national income is required. This argument is often expanded to include regional development and quality of life objectives.

As to the first premise, in the Canadian economy market forces normally facilitate the intersectoral channeling of factors of production from lower to higher productivity functions. The efficiency of the market place is somewhat blurred, however, by the above discussed characteristics of different energy industries and the presence of certain development incentives.

Increasing profit margins can be realized by energy industries in the high demand environment of the 1970's and 1980's even where there are no extra profits to be derived from an oligopolistic industry structure. The high risk nature of the business on the other hand, requires that the companies realize relatively high profits and cash flow generation if they are to continue to undertake major exploration and development projects.

If energy development was charged the aforementioned external costs and a reasonable share of the economic rents generated was collected for the Canadian public, this would put alternative development proposals on a more equal footing in the market place. It is, however, very difficult to quantify how important these factors have been or will be in investment decisions relating to energy development. An equally important question relates to what areas of the economy would provide for greater productivity gains than the energy sector in future decades and whether private capital is willing to risk investment in these areas.

On this latter question, any shortfall in expected energy investment would deflate aggregate demand only if the slack is not picked up by other investments

or greater fiscal stimulus. Any easing of price and exchange rate pressures and increased availability of capital should encourage greater investment in other sectors of the economy.

As to questions related to the second premise, employment generation is looked upon by many as an unqualified benefit. Clearly, employment is an important stabilization problem; it could also be looked upon as a cost when viewed in the longer-term context of the efficiency of resource allocation. It is a natural reaction for the businessman to minimize his costs, including labour, and maximize revenue. In a broader sense this is what is meant by productivity. It is equally valid for society to increase its income from productivity gains.

The shorter-term impact on employment of the investment phase of different energy development scenarios has been quantitatively assessed and the empirical results are discussed elsewhere. As it is logical to expect that the shorter-term employment effects of energy development would be similar to that generated by other capital projects of similar size and that the same employment effect could be realized at considerably less cost through government fiscal measures, the important employment effects relate to the longer term.

It is true that in most energy industries, the production processes are highly capital intensive. But there are pitfalls in the limited approach. If only the employment effect is considered attention must be drawn to indirect and induced as well as direct employment. If energy projects generate a relatively high income and it accrues to Canadians, the lower labour intensity of their operation means that income is continuously generated while human resources are released to be employed in other activities. A very important part of the improvement in our standard of living over the centuries has been due to the ever increasing output of the individual. Moreover, if the rate of growth of the labour force after 1980 declines as sharply as now anticipated, the secular unemployment problems of the late 1960's and 1970's may be replaced by a secular labour scarcity problem similar to that now prevailing in many of the European countries.

It is to be reiterated that the important factor when assessing the efficiency of resource allocation is that the sum of profits plus labour income of the low labour intensive energy sector should be compared with the revenues derived from possible alternative activities.

The justification for proposed energy projects rests with the above discussed longer run considerations. The issues of the timing and scale of energy development within a medium-term time frame should be viewed as important but secondary to the longer-term considerations. Many of the concerns raised as to energy development in the 1970's reflect apprehension as to the stress placed on the country's production capacity by the construction of these projects and the associated market dislocations and price pressures, including some appreciation of the exchange rate. The shorter-term output and employment impact of such projects may assist or exacerbate the realization of the stabilization objectives of the country. If large energy projects proceed by utilizing unemployed resources in the economy then the shorter-term benefits are unambiguous and the government's stabilization policy is assisted. Conversely, if demand activity is high and such projects are to proceed by attracting resources and capital away from other sectors of the economy and driving up wages and prices, then the net shorter-

term benefits from such developments are uncertain and the problems of stabilization policy are greatly exacerbated.

The argument could be advanced that shorter run effects of energy investment are generic and apply to every type of investment. As long as investments are made in tight market conditions, the upward pressures on price of wages, material, money, etc., will be greater than if there was considerable slack. This would adversely affect other industries which compete for exports and against imports and thus divert resources for particular investment activity. An important difference is, however, that most other types of investments can be timed at a pace more easily digestible by the economy than is the case with the very large energy projects, especially those in the frontier areas.

The ability of the government to regulate the economy within an acceptable range of capacity and manpower utilization is subject to practical limits. The possible 'bunching' of major energy projects would severely strain the capacity of the stabilization policy to offset such demand pressures. This points to the need to ensure that the construction of energy projects is not concentrated in a particular period and that they preferably proceed when the economy is not operating at full capacity. Thus, it is important to have some indication of economic activity and capacity in particular markets that would supply energy development and in the economy in general. It is also useful to refer to previous experience in accommodating resource development booms and to compare the relative magnitudes of such booms and the economic setting in which they took place with those projected for energy development in the 1970's.

It is important to emphasize here that a plea to justify large energy development projects on the basis of their employment generating properties or as a countercyclical stabilization tool, is unwarranted. This, though, is not to say that projects which are decided upon because of their income generating ability or other more strategic longer-run considerations should not be so timed that they could take advantage of under-employed resources.

The foregoing discussion and the earlier sections of this report raise the more critical issues to be considered when assessing the consequences of energy development. Many of them relate to a vital decision making process relative to the income generating ability of the different investment opportunities. In a way this is not very different from the problem facing the businessman when making his investment choices. For the national economy, however, there are additional problems which may not be always in total harmony with the principle of maximizing corporate returns. Apart from the environment issues there are, among others, regional economic problems (what may be good for some parts of the country may not be wholeheartedly supported by others), and also the question as to whom do the returns from the investment accrue and what is done with them. A further important question is the response of domestic energy prices to increased demands and international price pressures which may be superimposed on us by foreign markets. There are separate sections in this report dealing with ownership, rent collection and the impact of energy prices on Canadian industry. The problems are referred to above only to complement the issues which will have to be evaluated and analysed before the country can be committed to a route of energy development.

Economic Impact of the Investment Phase

An important problem is the economic impact of the investment phase. Reference has been made to the large capital requirements of energy developments in the future. A need exists to measure both the total capital resource requirements (direct, indirect and induced) of possible developments and the extent to which these requirements might have to be diverted from other sectors. Again, according to the analogy which has been used before, a businessman when faced with a new investment opportunity will want to know the expected risk-adjusted return and also whether the required investment capital is available to him or if he would have to divert it from some other venture. If the latter case is true, significant adjustments may have to be made in his operations, and his decision making criteria would be biased accordingly.

The problems faced by the national economy are complicated by the social costs that are often prevalent when such adjustments are called for. It is frequently not enough to decide that since a certain energy development project might yield higher and longer lasting profits than some marginally profitable small industries, the decision should be in favour of the development even if the small industries will be hurt. A solution will have to be found for these industries, if such a danger exists, in spite of the fact that their contribution to the national welfare is more limited.

A brief explanation of how these conflicts and pressure points arise, is offered in the next few pages.

Once an investment decision is made to proceed with a large energy project, the developers attempt to acquire the necessary capital on the financial markets. (The impact of supplying the capital from domestic or foreign markets is discussed later, together with the financial implications of appropriating Canadian and foreign savings to energy development.) The availability of financing represents, in fact, a claim on the productive facilities (labour and material) of the economy. Some of these resources may at times be unemployed while others would be actively involved in the production process. Moreover, some of the unemployed resources may not be directly useful for the type of endeavour required while at the same time there may not be a free capacity in essential resources (structural problems). This might have the consequence that, without directly ameliorating the slack in certain areas of the economy, intense pressures in other areas could develop. Although the re-spending of income and the generally higher levels of economic activities tend to spread to areas not directly affected by the investment program, at least a part of these benefits could be offset by price pressures. The spread of generally higher price pressures may hamper the export and import competing industries. It could affect the smaller domestically competing industries as well, whose financial strength and technological base would not allow them to absorb higher costs to the same extent that some of their more powerful competitors would be able to.

It appears that to the extent that large energy projects would call on resources employed in other activities (and not idle resources) the developing price pressures could be greater and more detrimental to both social and economic development in other sectors of the economy. The more interesting questions are to what degree

these conditions would develop, how large a part of the projects' resource requirements would be diverted from other productive activities and how serious would the consequential price pressures become? If these price pressures are relatively moderate they would not offset the benefits of higher personal income caused by the strong demand-driven economic activity stimulated by this investment. It may not affect substantially our internationally competitive position either and, even if there were some adverse consequences on our international trade, the improved domestic demand could more than take up any slack in exports. However, if the excessive demand caused by the investment drives up prices more than the increases in nominal disposable income and also considerably above those of our international competitors, the consequences for our economy and our standard of living would be very serious indeed.

Consider now the sourcing of the financing requirements for large energy projects. The crucial question here is not whether there are sufficient numbers of Canadian investors who are prepared to invest their funds in a large energy project. The more important aspect is whether total Canadian financial capital can supply all the country's needs, including the contemplated energy development. If the answer to this is in the affirmative (an unlikely event) it would make very little difference from the point of view of the exchange rate problem how large a part of a specific project is financed by foreign sources. If the foreign financing were unusually large in a single project, borrowers in other sectors could have greater access to domestic financing. If no incremental foreign financing were required the import content of large energy projects would exert a downward pressure on the Canadian dollar.

However, the expectation is that at least a certain portion of the capital requirements of energy development will not be sustained from traditional (domestic *cum* foreign) sources and incremental foreign financing will be needed. Under the prevailing floating exchange rate system, large additional foreign borrowings, if not offset by compensating increases in the current account due to the construction of the projects, may increase the demand for Canadian dollars and exert an upward pressure on its external value. The increased induced demand for goods and services as a result of the large investment project would stimulate capital requirements in other sectors of the economy with a resultant upward trend in interest rates. These higher interest rates may be responsible in our open international capital markets for further capital inflows, adding to the upward pressure on the exchange rate of the Canadian dollar. The consequences of this would of course be growing and cheaper imports and more expensive and declining exports.

If the appreciation occurs on account of large demands for long-term investment capital, the investment may contribute to income and productivity improvements in the more distant future. The higher exchange value would make current production internationally less competitive which would not be ameliorated by immediate productivity improvements and cheaper imports could displace domestic production.

An exchange rate appreciation, if it occurs as a result of energy investment, would fall into this category.

Again the more interesting question is when and by how much and how long would these last? The force and duration of such pressures is closely linked to the economic setting at the time they take place.

If the Canadian economy is running at or near full employment levels when specific major energy developments are launched, there will be practically no short run benefits from the investment. Inflation would increase substantially and all the resources required by the projects would be diverted from other activities. Clearly, if major energy developments are decided upon under such conditions, care should be taken by appropriate fiscal and monetary measures to stabilize the economy.

The case of a fixed exchange rate system has in many ways similar results. The increased demand for financial capital would exert pressures resulting ultimately in higher price levels. One of the main differences between the fixed and floating exchange systems is in the adjustment reaction of the domestic economy. The requisite deflationary measures in a fixed exchange rate system would hit initially a much wider segment of the economy, whereas under a floating exchange rate, the impact would be first felt by the export and import competing industries.

As the foregoing discussion indicates, excessive claims on both real and financial resources would create scarcity and as a result increase the general level of prices and interest rates. The import of financial capital—while it helps to overcome institutional rigidities arising from portfolio preferences—ameliorates in fact the strain on physical facilities only if it is used to acquire foreign real resources. The lowering of Canadian content in the investment may ease the pressure but at the same time it also foregoes the benefits to be derived from increased utilization of Canadian industrial capacity. Proper timing of projects may help the endeavour to have a maximum Canadian participation. It is to be remembered, however, that even if high import contents are associated with the investment phase of any venture, the increased production capacity would tend to increase the economic capacity and the income stream of the future.

The three vital considerations are that:

(a) energy development of the future will require large resource allocation. Whether or not those resources are momentarily unemployed or have to be diverted from other activities, the decision to commit them to the energy sector will have to be predicated on the need for the energy and the comparative advantage to be gained in terms of income generated and being made available to and for Canadians;

(b) the large resource requirements of energy development will undoubtedly create strains during the investment phase. The size of these strains and their impact will depend on the economic environment at the time they take place. If resources are not fully employed, considerable gains can be expected; although this should be considered as a by-product rather than a motivation for the investment. To the extent that resources are gainfully employed elsewhere, substitutions take place and the short-term benefits may become short-term costs;

(c) if income from Canadian energy development can be obtained (through royalties, taxes and economic rent collection) to a degree which would warrant their exploitation for other than domestic needs, development of major potential frontier resources might well take place within the next decade or so. This could help to defray the costs of energy supplies to Canadian markets and help maintain receptive export markets.

This study addresses itself to the estimating of the capital requirements of five investment scenarios, four of which reflect varying degrees of exports. Although these scenarios are only illustrative, they are linked to possible supply-demand conditions. The fifth investment scenario is based on a basically autarkic principle and reflects essentially domestic demand. A further step is then taken by estimating, with the help of an econometric model, the economic impact of the investment phase of these "hypothetical" situations.

The use of econometric models requires comment. Such models have both positive and negative properties and the clear understanding of their limitations is essential for their proper use.

Econometric models, in essence, quantify the interrelationships of the economy. In this capacity, they are helpful in understanding and estimating how certain events (for instance changes in investment, in consumption, etc.) might affect the overall and specific aspects of the economy. Their main virtue can be found in the aid they give the analyst (or policy maker) in assessing the relative force and direction of movements arising from certain events or policy decisions. Models are useful in the articulation and reformulation of intuitive insights into the behaviour of economic systems.

The working of the economy is, however, a many faceted, highly complex mechanism. There are thousands of interrelationships and equally numerous assumptions necessary to obtain a full picture. There is no econometric model which is error free and many have special weaknesses in certain areas while they may be better in others.

The CANDIDE model has been used to simulate the economic impact of energy investments. Its great advantage is its richness in industrial detail as it is the only Canadian model which incorporates input-output matrices. At the same time, the model is relatively new and there are sectors which are incomplete, notably the financial and balance of payments sectors. There are also difficulties with the price equations.

Another constraint of the use of econometric models is the assumptions relating to the economic setting. It is not possible to predict with great confidence the behaviour of the economy several years ahead. It would, therefore, be a serious mistake to consider any illustrative economic setting and the impacts on such setting as a prediction of future events. The impact study in this report simply indicates the overall resource requirements of selected energy investment scenarios and what would develop if the investment is made under a given economic setting. Under tighter market conditions the net gains would not fully materialize and the strains on facilities would be exacerbated.

The strain on the country's productive facilities, however, is not only a function of the degree of capacity utilization, but also of the efficiency of the basic resource reallocation. Different resource markets operate with different degrees

of efficiency. For example, labour markets are considerably less efficient than capital markets. Therefore, the social and economic costs of shifting resources between sectors will depend on the efficiency of the market reallocation process and this is not fully reflected by econometric models.

Chapter 2

CAPITAL REQUIREMENTS FOR ENERGY DEVELOPMENT

Five illustrative energy development programs for the 1970's reflect estimated future supply and demand conditions and indicate the possible capital requirements. The estimates of capital expenditures vary in a range of $42 billion to $68 billion depending on different rates of energy development.

Capital expenditure estimates for "Self-sufficiency Development" amount to 42 billion in current dollars. This reflects a slower rate of energy development compared to that of the last decade. The "Standard" and "Delayed Development" cases would total about 50 billion in current dollars. These development cases represent a more or less historical pattern of development with a Mackenzie Valley gas pipeline starting in 1975 or in 1978 respectively.

The "Extensive" and "Maximum" development cases anticipate capital expenditures of $60 billion and $68 billion respectively depending on additional northern development and pipeline projects. These expenditures would indicate that the Canadian economy from 1975 onward would be required to allocate over 5 per cent of GNP a year to energy resource development. This would represent a significant increase in the historical proportion of the energy sector spending to GNP with the exception of several resource boom years in the 1950's.

Non-residential private investment is notably volatile and difficult to forecast, even at the aggregate level over the short-term. The pattern of capital formation in the energy industry is similar to the sharp swings in total investment. It is useful to look at historical patterns of capital investment in the energy sector as one input to project capital requirements of this industry into the 1970's; but such projections should be looked upon as only a tentative survey of difficult terrain.

In the 1960's, total investment in the energy sector was $19 billion, an average of 3.2 per cent of gross national product. A recent projection of the Canadian economy for 1973-1980 from the CANDIDE model suggests that, based on a projection of observed historical relationships, capital investment in the energy industries would total some 47 billion in current dollars for this period. At first glance, this would appear to represent a very large increase in the average annual percentage of GNP going to energy investment. In fact, however, energy investment averages 3.6 per cent of GNP over the period. Moreover, this relative increase reflects in part the more general expectation that total fixed capital formation, after stagnating from 1966, will again surge ahead for several years in response to the renewed momentum of North American growth before moderating markedly in the latter part of the decade.

In this study, five investment scenarios for energy development in the 1970's have been considered in light of possible future supply and demand conditions in domestic and foreign markets. In all five scenarios, capital investments in electricity, coal, uranium, natural gas distribution and oil marketing are assumed not to diverge significantly from historical trends, except under the Maximum Development, Case D. As the James Bay Hydro project will be required to sustain growing domestic demand for electricity, the associated capital expenditures are therefore contained in all five cases. In the absence of the large James Bay project, several smaller power generating plants would have to be built to satisfy Quebec's projected energy demand and the total of investment requirements would approximate the same amount as the James Bay project. Capital expenditures on oil and natural gas production, however, are expected to be much larger than projections of historical trends would indicate: very large developments are anticipated in the frontier areas and in the oil sands. The energy cases described below vary primarily on assumptions as to which of these petroleum developments will go forth and when.

Again it should be emphasized that the cases which have been studied are purely illustrative of the type of development which might take place given various rates of resource development. The inclusion of oil pipelines rather than a northern railway for the movement of oil does not exclude the possibility of the replacement of a pipeline by rail movement. Neither does the inclusion of a specific project in one development scenario mean that it cannot eventually be grouped with other projects in a different time frame.

In all cases the estimates of capital expenditures implicitly reflect the fact that the major projects envisaged will have to cope with varying and sometimes costly environmental challenges. As the environmental criteria which must be met by these projects are in many cases not yet established, variations in the total capital requirements will of course take place. It is not felt that the changes which could occur for this reason would seriously distort the comparisons which flow from the analysis.

Case A—Self-sufficient Development

It assumes:

a) the maintenance of currently authorized natural gas exports only;

b) the export of crude oil not to surpass imports of oil for Canadian needs;

c) the construction of a Mackenzie Valley natural gas pipeline not to begin this decade;

d) the moderate development of eastern offshore gas and oil to begin in 1975;

e) the continuation of the present rate of conventional oil and gas development through to 1975 and then a marked decline; and

f) limited oil sand developments.

Total capital expenditure in this decade is estimated to be about 42 billion current dollars under this development case, requiring an 8.2 per cent annual average rate of growth compared to the rate of 10.7 per cent over the last decade.

Case B—Standard Development

It includes:

a) the construction of a Mackenzie Valley natural gas pipeline to begin in 1975, and for Mackenzie Delta natural gas to reach markets by 1978;

b) the development of eastern offshore gas and oil to begin in 1975;

c) the continuation of the present rate of conventional oil and gas development through to 1975 and then a gradual decline; and

d) the gradual increase of oil sand developments.

Total capital expenditure in this decade is estimated at about $50 billion under this case, requiring an average 10.1 per cent rate of growth. Because of the peaking of expenditures in 1976 and the sudden drop thereafter, the average annual rate of growth is lower than the 10.7 per cent historical growth rate.

Case C—Extensive Development

In addition to the developments noted under Case B, it includes:

a) the development of Arctic offshore oil and natural gas production capacity;

b) a Mackenzie Valley oil pipeline with construction in 1978-79, and some pipeline construction offshore and from Ellesmere Island;

c) oil production projects on Ellesmere Island and in the Mackenzie Delta to reach markets by the end of this decade; and

d) some additional oil sands and refinery developments.

Total capital investment in this decade is expected to amount to about 60 billion current dollars under this case, requiring an average 13½ per cent annual rate of growth.

Case D—Maximum Development

In addition to developments noted in Cases B and C, it includes:

a) the development of a uranium enrichment plant starting in 1977;

b) additional oil and natural gas production capacity on Ellesmere Island and in the Mackenzie Delta and offshore;

c) maximum development of Canadian oil sands potential and the expansion of refining capacity;

d) more development on the east coast and the development of Beaufort Sea and the Arctic Islands areas at the end of the decade; and

e) additional gas pipeline developments in Arctic and Beaufort Sea.

Total capital expenditures in this decade are estimated to be over 68 billion current dollars under this case, requiring a 17½ per cent annual average rate of growth.

The development of a uranium enrichment plant is included with the Maximum Development case which is, indeed, an illustrative case only. The uranium enrichment facility, however, may form part of any of the other investment scenarios within the framework of a realistic energy policy.

CAPITAL REQUIREMENT PROJECTIONS 1971-1980

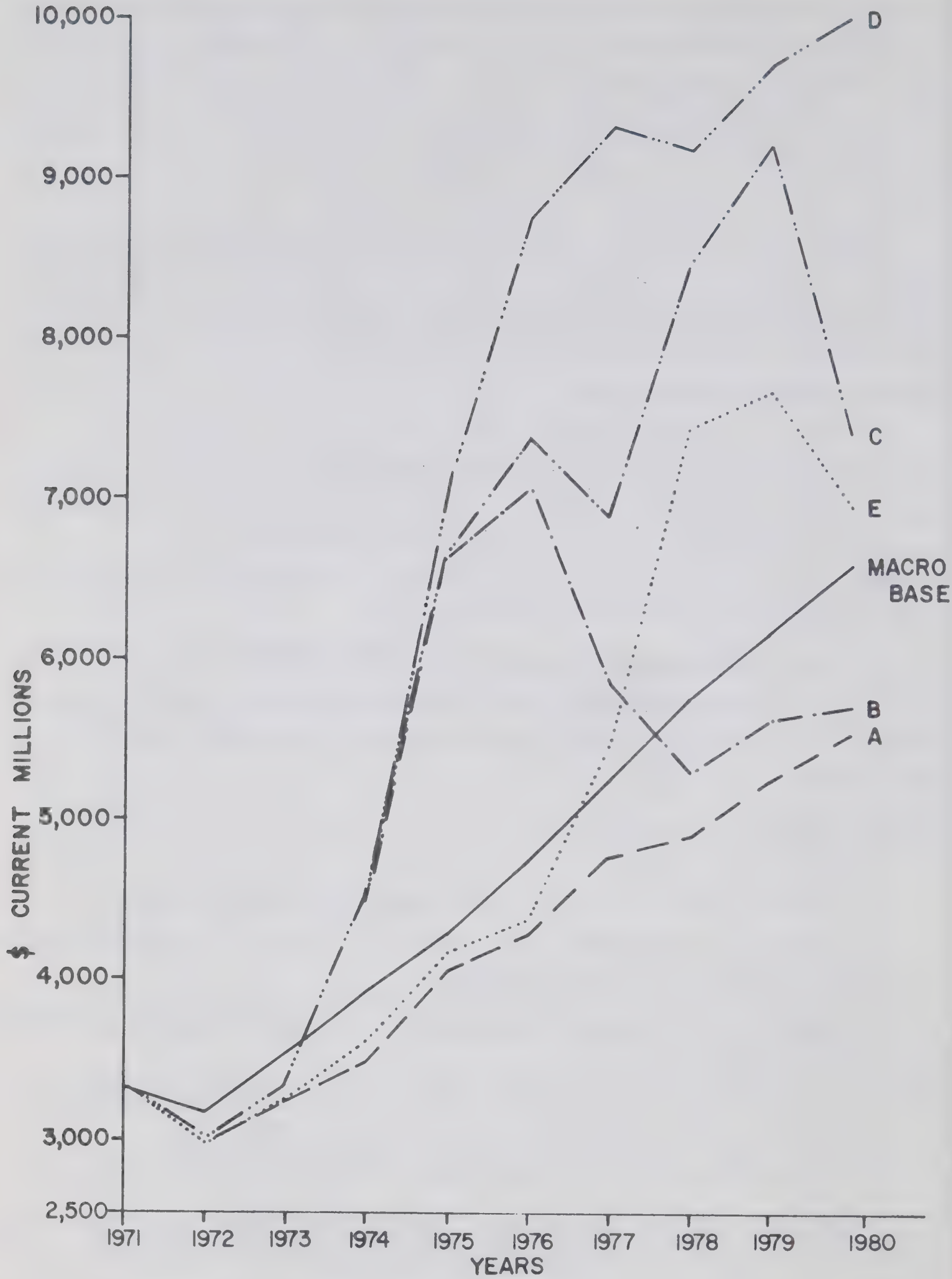

Chart 1

CAPITAL REQUIREMENT PROJECTIONS 1971–1980

	Historical Normal (Macro base)		Self-sufficient Development (Case A)		Standard Development (Case B)		Extensive Development (Case C)		Maximum Development (Case D)		Delayed Development (Case E)		Actual Investment (1961–1970)		
	Current $	*Constant* ($ 1961)	*Current* $	*Constant* ($ 1961)	*Current* $	*Constant* ($ 1961)	*Current* $	*Constant* ($ 1961)	*Current* $	*Constant* ($ 1961)	*Current* $	*Constant* ($ 1961)	*Year*	*Current* $	*Constant* ($ 1961)
1971*	3,311	2,392	3,311	2,392	3,311	2,392	3,311	2,392	3,311	2,392	3,311	2,392	1961	1,247	1,247
1972	3,170	2,249	2,969	2,087	3,019	2,130	3,019	2,130	3,019	2,130	2,969	2,096	1962	1,133	1,119
1973	3,511	2,445	3,250	2,240	3,300	2,282	3,300	2,282	3,300	2,282	3,250	2,250	1963	1,243	1,199
1974	3,940	2,660	3,500	2,395	4,550	3,059	4,550	3,059	4,550	3,059	3,600	2,447	1964	1,443	1,361
1975	4,272	2,869	4,050	2,698	6,650	4,376	6,650	4,376	7,100	4,728	4,150	2,782	1965	1,644	1,489
1976	4,724	3,144	4,275	2,825	7,075	4,599	7,375	4,791	8,725	5,637	4,375	2,906	1966	2,022	1,747
1977	5,255	3,424	4,775	3,096	5,850	3,766	6,850	4,383	9,300	5,895	5,450	3,523	1967	2,217	1,880
1978	5,775	3,669	4,900	3,094	5,275	3,329	8,475	5,238	9,175	5,678	7,425	4,620	1968	2,422	2,048
1979	6,177	3,816	5,225	3,213	5,600	3,445	9,200	5,528	9,700	5,848	7,650	4,640	1969	2,637	2,152
1980	6,595	3,989	5,525	3,334	5,700	3,451	7,400	4,409	10,000	5,981	6,950	4,155	1970	3,038	2,273
Total	46,730	30,657	41,780	27,374	50,330	32,829	60,130	38,588	68,180	43,630	49,130	31,811	Total	19,046	16,515

*Figures for 1971 are actual data from Statistics Canada.

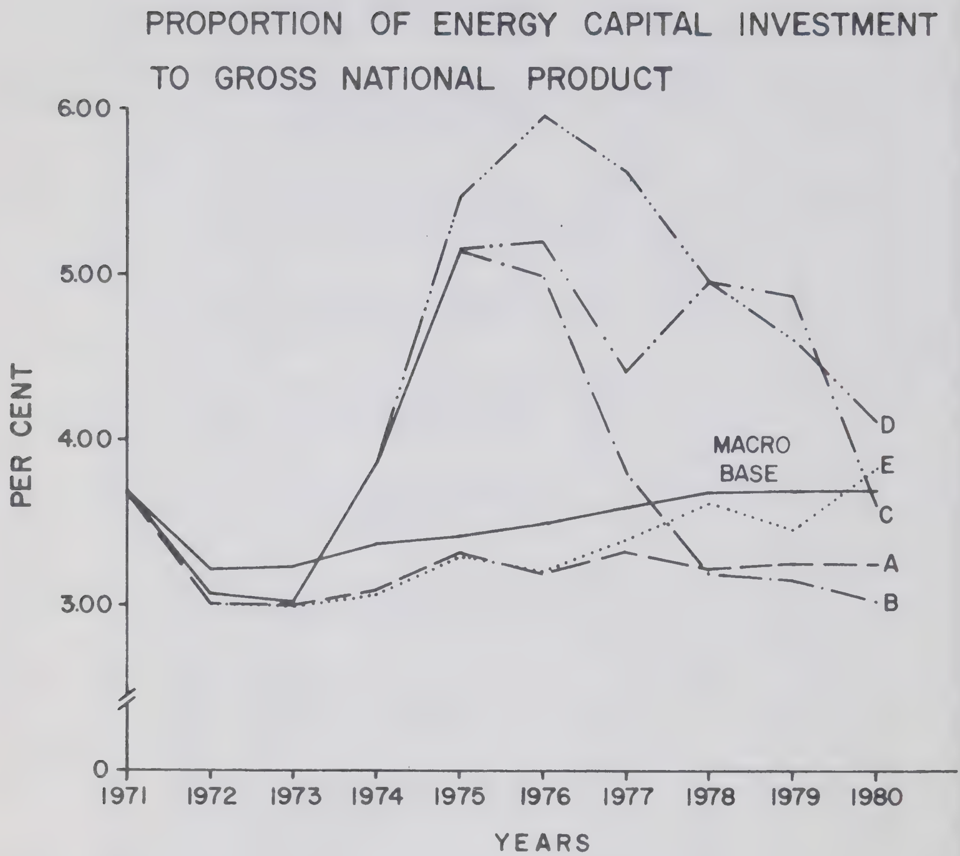
PROPORTION OF ENERGY CAPITAL INVESTMENT
TO GROSS NATIONAL PRODUCT
6.00
5.00
4.00
3.00
0
PER CENT
MACRO
BASE
D
E
C
A
B
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
YEARS

Chart 2

PROPORTION OF ENERGY CAPITAL INVESTMENT TO GROSS NATIONAL PRODUCT[1]

	Historical Normal (Macro base)	Self-sufficient Development (Case A)	Standard Development (Case B)	Extensive Development (Case C)	Maximum Development (Case D)	Delayed Development (Case E)		Actual* Proportion (1961–1970)
1971	3.67	3.67	3.67	3.67	3.67	3.67	1961	3.19
1972	3.21	3.01	3.06	3.06	3.06	3.01	1962	2.68
1973	3.23	2.99	3.03	3.03	3.03	3.00	1963	2.73
1974	3.37	3.08	3.84	3.84	3.84	3.07	1964	2.90
1975	3.41	3.32	5.14	5.13	5.45	3.30	1965	2.99
1976	3.49	3.19	4.99	5.19	5.95	3.22	1966	3.29
1977	3.59	3.32	3.81	4.41	5.63	3.69	1967	3.37
1978	3.67	3.22	3.20	4.96	4.95	4.62	1968	3.39
1979	3.68	3.26	3.17	4.86	4.62	4.45	1969	3.36
1980	3.69	3.26	3.03	3.61	4.12	3.83	1970	3.60
Average percentage (1971–1980)	3.50	3.23	3.69	4.18	4.43	3.59	Average (1961–1970)	3.15
							1956	4.16
							1957	5.31
							1958	3.99

*Figures are actual data from Statistics Canada.

[1]The GNP projections of the CANDIDE September model were used as base figures.

Case E—Delayed Development

Case E is similar to Case B with the following exceptions:

a) the delay in the development of Mackenzie Valley gas and oil production capacity; and

b) the construction of the Mackenzie Valley gas pipeline was assumed to begin in 1977 rather than 1975.

Total capital requirement for Case E is expected to be about $49 billion current dollars requiring an 11 per cent annual rate of growth.

The capital requirement projections of Cases A to E and the macro control base are presented in Charts 1 and 2 for the period 1973-1980 in both current and constant dollars. The estimates of capital expenditures under Cases B and E are fairly close to the macro projections of CANDIDE in terms of proportion to GNP, with marked diversions only during construction of the gas pipeline. Under Cases C and D, the Canadian economy from 1975 onward would be required to allocate over 5 per cent of GNP a year to energy resource development. It is noteworthy that for Case A this proportion would be 3.2 per cent compared to 3.4 per cent during the comparable period of the sixties.

As mentioned at the outset of this study, the focus of the economic analysis is the implication of a significant enlargement of the energy sector, motivated by energy exports surplus to domestic consumption requirements, although the situation described as "Canadian self sufficiency" is also included. The investment scenarios described in this section of the study reflect a range of possible supply/demand conditions, which are discussed in the chapters dealing with Canada's energy requirements and resources and from which the following has been extracted:

POSSIBLE SUPPLY-DEMAND OF HYDROCARBONS—EARLY 1980's

	Possible Development Cases				
	Self-Sufficient	Standard	Extensive	Maximum	Delayed
	A	B	C	D	E
			Million barrels per day		
Oil					
Supply (including imports)	3.2	3.6	5.2	5.5	3.4
Canadian consumption*	2.4	2.5	2.6	2.7	2.4
Exports (In Case A exports = imports)	0.8	1.1	2.6	2.8	1.0
			Trillion cubic feet per year		
Natural Gas					
Supply	4.1	5.2	5.7	8.7	4.7
Canadian consumption*	3.2	3.5	3.8	4.6	3.4
Currently authorized exports	0.9	0.9	0.9	0.9	0.9
Additional exports		0.8	1.0	3.2	0.4

*Including use by the energy industries in Canada; e.g. pipeline gas.

Chapter 3

SUMMARY OF FINDINGS

The economic impacts of five possible expenditure programs have been measured by using an econometric model and complemented by qualitative discussion. Viewed from the perspective of the control solution, the "Standard" and "Delayed" development cases, both costing about $50 billion could be absorbed, if there is moderate slack in the Canadian economy, without major consequences. There would be considerable benefits associated with these investment spendings in terms of gains in employment and income. The "costs", such as price and exchange rate pressures would not appear excessive and would be of short duration. The priorities of our society would not have to be rearranged to accommodate these cases. Under tight market conditions the potential gains would be less and the costs greater.

The three remaining cases range from a $42 billion Canadian "Self-sufficiency" case through a $60 billion "Extensive Development" case to a $68 billion "Maximum Development" case. All three, albeit in different ways, would influence considerably the structure of our economy and could involve the rearrangement of our socio-economic objectives.

The "Self-sufficiency" case could indicate a choice by Canadians to forego income generation from resource development and call on oil and gas resources at a pace dictated solely by domestic demand. It would allow greater capital and labour resources for higher growth in other sectors of the economy.

The "Extensive" and "Maximum Development" cases would endeavour to maximize income from resource development and in so doing could create pressures on prices and resources. The adoption of these illustrative programs would have to be accompanied by stringent monetary and fiscal restraints with a reordering of economic and social priorities.

This chapter presents a summary of the quantitative results of impacting the CANDIDE econometric model with different resource development investment scenarios. The impacts of the different expenditure programs were measured from a background simulation or control solution that exhibited a certain degree of slack and a particular cyclical pattern. A further discussion of the background simulation is undertaken in Appendix B. When interpreting the impacts, care should be taken to put the numbers into a conditional context—conditional on the type of economy that may actually exist when these expenditures take place. However, given the range of economic environments which might have been selected for the background simulation and the capacity of econometric models in general, and CANDIDE in particular, the numbers cited provide a useful insight into the possible macro economic consequences of the investment expenditures implied by alternative resource development strategies.

It is clearly necessary, however, to apply judgement to these quantitative results.

Self-Sufficiency

The results from the impact study with CANDIDE of the reduced investment expenditures required to sustain this particular resource program must be cautiously interpreted. They indicate the obvious—that a reduction in investment below that implicit in the macro base projection generates downward pressure on employment and real GNP. What is not indicated is that there may exist other attractive alternative outlets for Canadian savings and that the anticipated decline in energy sector spending will make these alternative development strategies more feasible. The casting about for other more diversified vehicles of growth could conceivably result in no net decline in investment spending.

What the magnitudes generated by the model can provide is an insight into the probable maximum reduction in Canadian economic performance consequent upon the selection of a self-sufficient energy resource program. While losses of over 10 billion dollars in real output and between 800 to 900 thousand man-years of employment are indicated this should by no means be interpreted as a realistic expectation. It is only in the unlikely situation that Canadians have no alternative means of achieving economic growth other than resource exploitation, a position not suggested by this report, that such numbers might be considered relevant. Furthermore, if a self-sufficiency program were to be implemented under tighter market conditions than those projected in the macro base, the importance of the release of scarce resources for other activities would be even greater. The possible advocacy of a policy of self-sufficiency does not envisage any slowdown in economic growth as a result of reduced resource exploitation, but in fact suggests that the goal of long-term economic growth can be most effectively met by choosing the self-sufficiency route. In this view, such policies would channel the country's resources into other types of activities.

Standard Development

The results from the study indicate that the increased investment spending requisite for the Standard Development case could generate between 7 to 11 billion dollars in real GNP and from 800 to 1,100 thousand man-years of employment, depending upon the level of Canadian content assumed in pipeline construction. In situations where the economy is approaching full employment of all resources, i.e. without either the cyclical troughs or the measure of slack apparent in the CANDIDE September Model control solution, the potential gains would be less. In fact the size of the employment generated might be interpreted as a measure of the resource reallocation that would need to take place in case of full employment. The study results indicate the existence to some degree of upward pressure on prices during the years of construction of the Mackenzie Valley natural gas pipeline in 1975 and 1976.

From the perspective of macro base solution levels, and relative to impacts of the other resource development programs, it would appear that the stress placed on capacities, i.e., both the capacity to produce, and the capacity to efficiently reallocate the requisite factors of production, is of relatively short duration and may, furthermore, not necessitate any rearrangement of national economic and social priorities.

Extensive Development

The investment expenditures requisite for the implementation of the Extensive Development case have an even greater impact on the Canadian economy. Depending on the level of Canadian content and the status of the economy, the increases in real output over the decade could range from 16 to 23 billion dollars and an increased employment generation of between 1,500 and 2,000 thousand man-years. The results of the impact study must be cautiously interpreted and considered to be conditioned by the economic setting of the base projection. Indeed, the magnitude of the employment generated suggests that in a decade of sustained high rates of growth, accommodation of two pipelines would present a serious strain on both the productive capacity of the economy and the capacity of the economic system to efficiently reallocate resources. A quite unsatisfactory price performance after 1977 and rates of unemployment below realistic full employment levels from 1976 onwards, combine to suggest the need for considerable accommodation with some rearrangement of other national objectives. The movement of already gainfully employed factors into resource development related employment, becomes a distinct cost perhaps observable even in an economy with slack capacity.

Maximum Development

The large incremental investment expenditures required for the Maximum Development case have a substantial impact on the economy, generating between 31 and 44 billion dollars in real output during the balance of the decade and from 2,900 to 3,400 thousand man-years of employment, depending on the level of Canadian content. Even with some slack in the economy there is severe stress of the country's capacities. The rates of price increase as the decade closes are as unacceptable as the projected unemployment rate of below 2 per cent in 1977-80 is unrealistic. The adoption of this program, presented primarily for illustrative purposes rather than as a realistic possibility, would necessitate a substantial reallocation of both human and capital resources even under conditions of slack. If it were to proceed in a tighter economic environment, it would be extremely difficult to accommodate. Even with some unused capacity, the adoption of this program would have to be accompanied by stringent monetary and fiscal restraint with a re-ordering of economic and social priorities not merely for the short term but for the decade.

Delayed Development

The decision to phase energy development towards the end of the decade, and in particular to delay construction of a major pipeline until 1978, can be expected to reduce the net increases in real output and employment during the decade from that which might occur under Standard Development case. The increases over the decade in real output range between 1.4 and 3.4 billion dollars and the employment generated between 200 and 340 thousand man-years, depending upon the level of Canadian content assumed. As with each of these programs, a tighter background simulation would reduce the real gains hypothesized above, but in general the option of delaying pipeline construction might appear attractive inso-

far as the stresses are placed upon a somewhat larger economic base. The choice between the Standard and Delayed Development cases will, of course, be based on much more than the income and employment generating effects of resource investment spending in this decade. Part of this decision would evolve around the relative gas price and development cost expectations which are the core of the "now or later" issue.

Balance of Payments

One of the major difficulties of constructing an econometric model for the Canadian economy is that the economy is an open one. Canada exports a very large share of its real domestic product and imports a high proportion of its total consumption. Thus the economy is vulnerable to fluctuations in the volatile international financial and commodity markets.

In the absence of the different energy development cases, the maximum current account deficit forecasted by the econometric model for the decade is 0.5 per cent of GNP in the years of high demand activity before climbing to a surplus of 0.6 per cent of GNP by 1980. The current account balance tends to decline significantly as the economy approaches full capacity and to increase thereafter as the growth rate moderates. These figures compare to a maximum current account deficit of 4.3 per cent of GNP during the 1950's and a maximum of 2 per cent during the 1960's when foreign economic conditions were favourable. This indicates an improvement in the ability of the Canadian economy to provide savings to meet domestic investment requirements.

Capital Account

In this setting the additions to energy investments in the 1970's which are associated with the different options would be accompanied by foreign direct investment and increased sales of Canadian securities abroad. Moreover, the consequent stimulus to aggregate demand would induce further additions to capital stock in other industry sectors, especially in those industries that supply energy development. This induced investment in turn could require further foreign capital inflows.

Although the inflow of foreign capital would be substantial in absolute amounts and, due to institutional factors, disproportionately higher in the special energy projects envisaged, this does not imply that this inflow of long-term capital would exceed proportions of previous resource boom years.

Current Account

The resulting surplus on capital account would have to be offset by a deficit on current account if a viable balance of payments is to be maintained. The current account deficit represents the real equivalent of the monetary capital inflows.

Investment in energy development has historically led to an immediate direct increase in imports of machinery and equipment and other construction materials. As the level of Canadian content of pipeline development in the 1970's is expected to be considerably lower than that of smaller projects in the past, the immediate direct increases in imports should be correspondingly larger. In addition, the consequent increase in real output and income would lead to increased demand for imports, albeit with some lag.

Depending on the proportion of foreign financing associated with the increased investments, their import content and the state of the economy, the decline in the current account associated with the income effects, may or may not be sufficient to fully offset the increased capital inflows. In a later chapter attention is drawn to the resource development boom of the mid-1950's. Some appreciation of the exchange rate was required in 1956-57 to further stimulate imports and hinder exports thereby bringing balance to our international payments position. This period also provides a good example of a decline in the current account associated with increased investment activity being larger than the inflows of foreign capital. The exchange rate declined in 1955 by over 2.5 per cent when long-term capital inflows to finance domestic investment were relatively low.

The empirical study based on the economic setting of the CANDIDE September model suggests that as real exports of goods and services, other than petroleum products, are assumed to grow at a constant rate over 1970-80, the impacts of the different development cases on the current account would be determined by their impact on the imports of goods and services. The decline on the current account position with each of the development cases reflects the size of the capital inflows to be accommodated. The deficit with the Maximum Development case is much greater than the other cases and by 1980, it reaches a maximum of 5 billion current dollars or about 2.5 per cent of GNE. With the other cases, when the current account deficit is measured as a proportion of GNE, the maximum levels are never above 1.5 per cent and this is reached only during construction of the Mackenzie Valley oil and gas pipelines.

Exchange Rate

Canada's past experiences with large resource development booms would suggest that with the Maximum Development case at least, the large long-term capital inflows would not be fully offset in the latter part of the decade by the decline in the current account related to the associated income effects. This would require temporary accommodation through short-term capital outflows and increases in foreign exchange reserves, appreciation of the exchange rate and an increase in the pace of domestic price advance. The analysis of the mid-1950's period suggests that any appreciation of the exchange rate would not be as marked as in 1956/57 because of the increased ability of the economy to meet its investment requirements and because of the anticipated lower levels of Canadian content in frontier area development.

The projected impact of the Standard Development case on the domestic macro variables and the estimated behaviour of the current account over 1973 to 1980, suggests, however, that no significant change in the terms of trade would be required with this option. There would probably be some need of short-term accommodation for inflows of foreign exchange during pipeline construction in 1975-76. (It is to be noted that there are at least two other econometric studies of which one supports this view while the other concludes a significant appreciation.) The differing results are associated, among others with different assumptions about the economy and the financing of the projects.*

*Institute for Quantitative Policy Analysis, University of Toronto—University of B.C. Centre for Continuing Education.

The Extensive Development case is somewhere in between as to the required accommodation in the external sector through exchange rate appreciation. Relatively large foreign capital inflows are required from 1975 and the current account position, in the absence of the different energy options, is expected to improve over the latter part of the decade and may even reach a surplus of $1 billion by 1980. Although the trade diversification associated with the Extensive Development case, and with the Maximum Development case, would shift the current account to a deficit position, the large capital inflows should result in basic balance surpluses and lead to upward parity value pressures. This would adversely affect the competitive position of Canadian export and import-competing industries with important implications for the federal regional development programs of income and employment maintenance.

Chapter 4

AN HISTORICAL COMPARISON, AND THE MEDIUM- AND LONGER-TERM ECONOMIC PERSPECTIVE OF ENERGY DEVELOPMENT

International demand for energy and the possibility of surpluses of supply in Canada suggest that Canadians may wish to consider accelerated energy developments in the coming decade. An analysis of the resources boom of the 1950's provides an historical precedent which may be an indication of the extent to which the necessary adjustments to the economy could be required and could be accommodated.

There have been concerns and uncertainties expressed about the wisdom of pursuing extensive resource development. It is not suggested that this is the only, or even the best, economic strategy for Canada. Medium and longer term analysis does, however, illustrate that if energy development is decided upon, based on productivity and income distribution considerations, then the investment in large energy projects could have substantial benefits to Canada.

(A) Resource Development Boom of the Mid-1950's

Historically, the economic impact of periodic resource development booms in Canada has been governed in large part by the nature of the individual projects and the state of the economy when they came on stream: the geographic distribution of the projects, their labour, machinery and material requirements, the degree of excess capacity in their particular markets and in the economy in general. To the extent that past resource development projects were able to use unemployed resources, the economy has realized very substantial gains in output and employment. At times, however, the basic resource reallocation implied by resource investment booms has involved serious market dislocations and price changes, including some appreciation of the Canadian dollar in foreign exchange markets. Such situations usually occurred when the development projects tended to have high Canadian content, high foreign financing and had to compete for capital and Canadian goods and services in tight market conditions.

Even in these most adverse circumstances, there have been some positive effects. Energy projects were successful in competing for capital and Canadian factor inputs, thereby displacing resources allocated to existing economic activities or alternatively proposed investments. The profitability criteria would suggest that there was a real economic gain to the country from a more efficient allocation of resources. For the petroleum industry, a qualification is required in recognition of the development incentives to this industry and its structure, in which, market influence tends to be concentrated in a few companies. Frequently, these energy projects have also had important research and development benefits and guaranteed export markets. In addition, they have led to the broadening of the Canadian

industrial base, to the development of domestic capital markets, and in some instances, to providing important infrastructure in underdeveloped areas.

In discussion of the potential shorter term impact of energy development in the 1970's, reference is usually made to the experience with the resource development boom of the mid-1950's. It is perhaps useful to the public debate to analyse briefly the forces dominating this particular boom period and to draw out any conclusions that appear relevant to energy development possibilities in the 1970's. Particular attention is focussed on the influence of long-term foreign capital inflows on the balance of payments and the exchange rate.

Economic development in Canada has followed the pattern of periods of concentrated growth and change, interrupted by extended periods of relatively slow growth. The early and mid-1950's was such a period of strong economic expansion. The cyclical upswing in the economy from the second half of 1954 through 1956 was founded on a strong surge in investment activity, particularly in the primary resource sectors and not on widespread strength in internal and external demand forces. General demand forces weakened further in the latter part of the decade leading to a prolonged period of slow growth and high unemployment which did not terminate until the early 1960's. A simultaneous downturn in the U.S. economy and a shift in monetary policy to a position of restraint in a recessionary period also contributed.

After a short-lived recession in 1953-54, the economy realized a strong advance in real output and employment in 1955. Real gross national product increased by almost 10 per cent and the unemployment rate decreased by over half a percentage point to under 4 per cent. The growth in investment activity was an important factor in this expansion but it was not the dominating force as in 1956 and 1957. The deficit on current account increased in 1958 reflecting the strong growth in output and income. Also important were large imports of capital goods and construction materials associated with the greater investment activity. Canada had a flexible exchange rate system during the 1950's and the value of the Canadian dollar in the exchange market actually declined in 1955 from U.S. $1.025 to below parity. This decline reflected the anomaly that long-term capital inflows were down in a year of high investment activity. Also important was the adjustment of the exchange rate from unrealistically high levels prevailing in 1954. Canadian monetary policy had lagged behind the United States in responding to the recession, and this led to large short-term capital inflows and an appreciation of the Canadian dollar in 1953 and 1954.

In 1956, the economy again experienced strong growth, primarily in response to a further sharp increase in the level of domestic investment. Real output advanced by over 8.5 per cent during the year, while investment increased by almost 20 per cent. Pressures on the economy's productive capacity were evident in the further decline in the unemployment rate to almost 3 per cent by mid-1956 and also in the sharp increase of the consumer price index. This pressure on the country's limited resources was ameliorated somewhat by large capital inflows to finance resource development projects. The deficit on current account was substantially larger than in 1955 reflecting the higher level of investment activity. This deficit was more than offset by capital inflows, and the Canadian dollar appreciated sharply in the second half of 1956 to about U.S. $1.04 at year-end. The exchange

rate continued to appreciate in 1957, to a post-war peak of U.S. $1.06 in August, 1957 under the influence of even greater inflows of foreign capital. Investment in 1957 accounted for over 25 per cent of gross national product and was one of the few forces resisting the general weakening of aggregate demand.

Analytical studies of this period are unanimous in the conclusion that the appreciation of the exchange rate was determined largely by the extent of the reliance on long-term capital inflows to finance domestic investment. Private short-term capital inflows appear to have been an important stabilizing factor in that sharp movements in the exchange rate were resisted. The current account appears to have responded relatively quickly in effecting the transfer of real resources implicit in the monetary capital inflows. Unfortunately, there are important statistical limitations to isolating the influence of relative price changes on the current account position.

Some of the appreciation in 1957 might be explained by the downturn of the economy and the consequent improvement in the trade account, despite the large imports of capital goods and construction materials required by the investment projects. The Canadian external sector is sensitive to cyclical factors. Domestic demand for imports is greatly influenced by the buoyancy of aggregate demand while the strength of export sales is largely determined by economic growth in our major trading partners. The evidence for 1957 is somewhat mixed in that the United States economy experienced a more pronounced downturn in 1957-58 than did the Canadian economy, thereby limiting the growth in export sales and consequently the improvement in the current account. Similarly, monetary and fiscal policies which dominated exchange rate movements in 1958-59, do not appear to be an important influence in 1956-57.

The prospects for the Canadian economy in the early and mid-1970's parallel the experience of the 1950's in that a strong surge in investment activity is widely anticipated after a period of stagnation from 1966. It is thought that investment could again approach 25 per cent of gross national product. While the medium-term considerations pertaining to the impact on the balance of payments and the exchange rate of alternative energy development options are discussed in the previous chapter, it is useful to examine what the requirements for foreign capital would be with the different energy cases for the remainder of the 1970's relative to the requirements of the mid-1950's.

The deficit on current account as a percentage of gross national product is an important indicator of the dependence on foreign resources for growth. With the Maximum Development case, for example, the CANDIDE model estimates that the maximum percentage of GNP represented by the current account in any one year does not exceed 2.5 per cent. This compares with a 4.3 per cent figure for the current account in 1956 and 1957. The increased ability of Canadian savings to service investment needs reflects the development of the economy to a more mature industrial state.

The major determinants of exchange rate movements in the 1950's were the levels of investment activity and the extent to which the economy required foreign capital. In 1956 and 1957, total investment represented about 25 per cent of GNP each year. With the Extensive and Maximum Development cases in the second half of the decade the levels of investment activity would approximate those of 1956-57.

Analysis indicates that the dependence on foreign funds to service domestic investment with the different energy cases, however, does not reach above 11 per cent in any year even when considerably higher levels of foreign financing are assumed for pipeline construction than observed historically. This rate compares to over 18.5 per cent in 1956 and 15 per cent in 1957. This would suggest that the required maximum change in the terms of trade would be considerably less than the appreciation of the exchange rate in the period 1956-57.

This view is supported by the circumstances surrounding the exchange rate decline of 1955. Foreign capital financed only 6 per cent of the total investment activity in this year, while the deficit on current account increased in response to the demand for imports associated with the high import content of domestic investment and the higher levels of output and income. This points clearly to the need to consider factors, other than capital inflows, in assessing the balance of payments and exchange rate effects of energy development projects. The upward pressures on the exchange rate in the 1970's will be further diffused if the import content of pipeline development turns out to be larger than that observed in the post-war period. This will probably be the case in the absence of government initiative to the contrary. The huge size of the project and the new technology involved in frontier area development would tend to lead to greater international participation than would be the case in more conventional pipeline construction.

Any appreciation of the exchange rate would affect the competitive position of import-competing and export industries. The more interesting question is the extent to which the sales of particular industries are affected by given changes in the exchange rate. It is to be remembered that any increase in a country's exchange rate has important consumption benefits in that a country's currency is able to command relatively more foreign products.

In summary, the foregoing discussion suggests that the adjustments of resources to accommodate accelerated energy development in the 1970's is not all that large when viewed from an historical perspective, and could be accommodated in the course of adjustment of the Canadian economy to medium-term shifts in demand and supply. The experience of the past suggests that with proper timing and economic management, considerable benefits could inure to a long-range economic strategy.

(B) A Medium- and Longer-Term Perspective of Energy Development in the 1970's

The analysis of possible demand/supply environments for Canadian energy development in the 1970's indicates an enlargement of the energy sector, especially if it is decided that Canada should continue as a net exporter of petroleum products. Critical to this decision is the size of the potential resource base for hydrocarbons and the pace of resource exploitation implicit in the energy development cases discussed. If energy development is to be restrained to supply only domestic consumption needs, energy investment would then account for approximately the same proportion of Canadian gross national product through to 1980 as in the 1955-70 period. In this circumstance, the problems of adjustment to accommodate energy development in the 1970's are essentially mitigated. It would, however, raise a number of other important questions such as the timing and extent to which the

country might rely on imports of petroleum and alternative domestic sources of energy. A general question relates to the ability of other sectors in the economy to efficiently employ the country's growing labour and capital resources if there is any shortfall from projected energy investment. The discussion of this chapter relates to the medium and longer term considerations involved in a possible enlargement of the energy sector.

Different concerns have been expressed that the large projects now under consideration will unduly strain the country's resources, thereby creating inflation and serious dislocation of markets over the shorter term, especially if there is any bunching of projects. From a longer term perspective, there is a general apprehension that there will be a significant resource reallocation to the energy sector which would somehow not be consistent with Canada's socio-economic priorities. A particular concern often voiced is that, because large foreign capital inflows will be required to finance these projects, and because some of the projects would be oriented to servicing U.S. markets, there would be strong upward pressure on the exchange rate. A higher value for the Canadian dollar is held to be bad for the country as it would lead to a deterioration in the competitive positions of Canadian export and import-competing industries, particularly in the manufacturing sector. It is thought that the consequent loss of jobs in these industries might even be greater than the increased employment opportunities associated with the energy projects. A sometimes corollary to this argument is that the government should act to limit primary resource development and drive down the exchange value of the Canadian dollar in order to create a climate conducive to increased growth in the manufacturing sector. In turn, it is held that this would provide the required employment opportunities for Canada's fast growing and highly qualified labour force.

As discussed in an earlier chapter, the diverse issues underlying such concerns will need to be reconciled if Canada is to have a comprehensive energy policy that contributes to the achievement of the socio-economic goals of society. These issues, however, have many ramifications which are not susceptible to neat economic analysis leading to hard policy recommendations. They involve not only the ordering of the country's future economic and social needs but also a view of the international economic environment of the 1970's and 1980's.

At this stage of public discussion, the analysis has been more modest in scope. This report attempts only to answer the essential question as to the possible strains exerted on the country's resources from the construction of large energy projects. An important feature of the analysis is to identify where pressure points in the system might develop in accommodating the different energy projects. It is only with such information that the degree of symbiosis between the various energy policy objectives and short-term stabilization goals can be evaluated.

This chapter sets out the more important medium- and longer-term economic interrelationships that would be involved in the adjustment of the economic system to increased energy investment. There is no attempt to compare the impact of similar investments in other sectors of the economy with that of increased investment in the energy sector. To do so would require information as to the investment opportunities of a wide range of Canadian industries. In turn, this would require demand and supply analyses of the different industry groupings similar to the

studies undertaken for the energy industries. Such a comprehensive comparative analysis of alternative investment opportunities is not possible at this time. In the absence of this analysis, it is to be recognized that the growth opportunities of other sectors might prove to be as attractive or more attractive than investment in the energy sector. Similarly, it is most probable that other investments of the magnitudes envisaged in the energy sector would have at least as great an impact on the economy during the construction phase. The important questions to be answered are the extent to which alternative opportunities are present and then how they compare as to relative income generation to Canadians whether through labour income, profits or transfers via taxes on either source. To this end, there is a discussion of the role of the market place and of government in determining the allocation of capital and factors of production, given the characteristics of the energy industries, and in particular the petroleum industry.

At the outset, it is perhaps useful to establish the dimensions of proposed energy development projects in relation to the total economy and the magnitude of adjustment required. For instance, if a Mackenzie Valley natural gas pipeline is to be constructed, capital formation in the energy sector in the years of pipeline construction would average less than 5½ per cent of gross national product a year if built starting in 1975-76 as in Cases B and C, and less than 5 per cent if started in 1978-79 as in Case E. These figures compare with energy investment of 5.3 per cent of gross national product in 1957 when such large projects as the TransCanada pipeline, were under construction. The investment of $5 billion in a pipeline would, of course, provide an important stimulus to aggregate demand in the economy which might involve some reallocation of resources to the energy sector and some dislocative effects of moving resources into and out of the construction of energy projects. At the same time, a Mackenzie Valley pipeline would require a resource allocation to the energy sector of less than 2 per cent of total output each year during the construction period. While some shorter term accommodation would probably be required, such an adjustment is not large when viewed in relation to the growth potential of the economy or to the changes in the structure of production that take place in the normal course of medium-term adjustment to changing patterns of demand and supply.

Employment

The presence of unacceptably high levels of unemployed human resources, and the prospect of only minor deceleration in the very high growth rate of the Canadian labour force over the remainder of the 1970's, has led the government to give continued emphasis to employment objectives in the formulation of Canadian economic and industrial policies. Public debate of the potential social benefits of proposed industrial development, unfortunately, has tended to concentrate on direct job creation.

Clearly, the direct employment generated per dollar of energy investment or per dollar of energy sales is very low relative to some manufacturing or service industries. This does not, however, indicate that an enlargement of the energy sector is less beneficial than a comparable enlargement of more labour-intensive industries. To make such a judgement, consideration would have to be given to

the relative output and income effects and to any associated non-quantifiable externalities such as pollution, regional development, technological innovation and the creation of public infrastructure.

When limiting the analysis of relative benefits of alternative investment projects to employment generation, and again there are pitfalls in such a limited view, the indirect and induced employment effects, as well as the direct effects, have to be taken into account. To the extent that there may be a secular unemployment problem in the 1980's, the long range employment benefits from an enlargement of the energy sector in the 1970's centre on four areas. The first area is the employment opportunities in the energy industries. The earlier discussion of employment in these industries has related that such operations are and will remain highly capital-intensive. Second, the prospect of further large energy resource developments in the frontier areas and on the continental shelf in the 1980's and 1990's suggests an opportunity for continuing markets for particular domestic suppliers of energy development in the 1970's. The empirical study of the impact of the construction phase of different energy projects indicates, as previously detailed, that the total employment generation is considerable and widespread. A third area relates to employment opportunities in those industries that service energy production. Again, the earlier chapters on energy sector employment point out that energy service industries are relatively labour intensive and thus the indirect employment factor is significant. The final and probably most important area relates to the employment opportunities associated with the income-generating potential of energy industries, whether it be in the form of profits, labour income or transfer payments arising from taxation and the various means of economic rent collection. The demand and supply analysis indicates that the future investment opportunities in this sector may well be attractive. What is important to the national interest is the extent to which such income remains in Canada and this in turn will largely depend on the degree of foreign ownership and government policies on economic rent collection.

It should be recognized that the prevailing view that Canada has a secular unemployment problem might have to be altered after 1980 with the anticipated decline in the rate of growth of the Canadian labour force. While the average rate of labour force growth is expected to approach 3 per cent in the 1970's, it may decline to below 2 per cent average in the 1980's. It is conceivable that in 15 to 20 years, Canada might enter a period of relative labour scarcity. In this situation, it will be more attractive to have an enlargement of those industry sectors which generate relatively large income flows to Canadians and are not labour-intensive.

The impact on employment of the construction phases of the different energy cases should be viewed essentially within a medium-term cyclical context. The empirical work indicates that if some of the large energy projects now under consideration proceed, there would be important shorter term gains in real output and employment. For example, the model projects the decline of the average rate of unemployment from an enlargement of the energy sector in the period 1973-1980 to range from a ½ percentage point with the Standard Development case to almost two percentage points with the Maximum Development case. It is doubtful, however, that this employment effect is markedly different than that available

with many alternative capital projects; it would certainly involve a much greater capital outlay for the same employment effect than available through fiscal policy measures. In the same vein, an attempt to justify a Mackenzie Valley pipeline on the basis of short-term employment or income generation effects would be ill-advised. When short-term changes are the sole focus of policy, then policy levers of a similar orientation are best utilized. A Mackenzie Valley pipeline is simply too large and has too many important long-run implications to be viewed in this context.

It is also important that the realization of higher growth in real output and employment over the medium term does not generate excessive pressures that would divert the economy from attainment of other goals such as reasonable price stability and an equitable distribution of income. It is generally accepted that there is some form of shorter term trade-off between the attainment of employment and price objectives, but also that the relationships between employment levels and rates of price increase are complex and indirect. It is to be expected that the increased demand for labour emanating from the different energy projects would lead to increasingly upward pressures on the general level of wages in the economy, and eventually through complex wage-price links, to upward pressures on end-product prices.

It is conceivable that the pool of unemployed labour might decline past the so-called full employment level where further depletions would impair the productive efficiency of the economy. The reference above to an average 2 per cent decline in unemployment with the Maximum Development case is a good example of this. With this development case, the economy is clearly overheated and the increase in employment can no longer be simply looked at as a gain. In this case, there are costs to concentrating such large investment projects in so brief a period. It is not possible to meet all the associated demands from unused labour and production capacity and thus, if these projects are to proceed, resources have to be attracted from other sectors for a short period and primarily through price and wage increases.

It is also conceivable that even though total unemployment declines, particular regional employment problems might be exacerbated: upward pressure on wages, capital and material costs would hinder the competitive position of local industry and their ability to sustain regional employment and income levels. In the same vein, structural characteristics of the Canadian labour force introduce a real possibility of bottlenecks developing in certain labour markets quite independently of the general level demand for labour. This problem is always more serious when demand is concentrated in a single area and in projects whose completion date has a decisive impact on their ultimate profitability.

When large energy projects are carried out in periods of relatively high unemployment and excess production capacity, the output and employment gains are greater and pressures on domestic prices are less than when tight supply conditions prevail. For example, if there is some slack in our economy when a large project such as a Mackenzie Valley pipeline proceeds, then the construction of this pipeline would lead to a significant decline in the level of unemployment. If the model's projection of unemployment in the mid-1970's proves correct, then empirical study suggests that this decline would not proceed past the lower limits

of any realistic full-employment target for the 1970's. This, of course, holds true for any alternative investment package of similar magnitude proceeding in this period.

If oil reserves justify a second Mackenzie Valley pipeline to be built in the decade, along with extensive oil sand development and other major projects such as the construction of a uranium enrichment plant, the dimension of the required adjustment becomes more difficult. If this situation arose, energy capital formation as a percentage of GNP after 1975 would remain above 5.75 per cent a year. This implies that the stresses associated with resource reallocation are not only sustained but tend to pile up.

Generally, the stimulus to employment and output for different industry sectors is directly related to the size of the additional investments. The rates of increase in real domestic product are greatest for those industries which supply energy development such as the construction, the iron and steel industry and the metal fabricating industry. Employment growth is related directly to industry output but the distribution of employment effects also reflects the wide variation in capital/labour ratios. As illustrated below, it is apparent that energy development, even in the remote frontier areas, would provide an important stimulus to production and employment over the whole economy in the 1970's. Moreover, it is evident that the indirect and induced employment generated by the associated increases in output and income would far outweigh the increases in direct employment associated with the construction and operation of the different energy projects. The prospect of further large energy resource developments in the frontier areas and on the continental shelf in the 1980's suggests an opportunity for continuing markets for particular domestic suppliers of energy development in the 1970's.

GROWTH IN EMPLOYMENT BY SELECT INDUSTRY GROUP*
WITH ENERGY DEVELOPMENT CASES B, C & E—1973–1980

	(B) Standard Development — Canadian Content		(C) Extensive Development — Canadian Content		(E) Delayed Development — Canadian Content	
	High	Low	High	Low	High	Low
Total (in thousands of man-years)	1,084	767	1,965	1,404	343	200
Manufacturing	152	74	280	145	34	—
Services	316	227	538	381	97	62
Transportation	139	111	234	183	51	39
Construction	87	81	196	196	48	43

* As measured against the macro base projection.

On the question of the degree of Canadian content to be actively encouraged in energy development, again the criteria to be used should not be short-term output and employment considerations but rather the longer term growth potential of particular industries to supply future energy development in frontier areas and offshore, not only in Canada but worldwide. It is only by fostering the growth of industries with such international potential that Canada will ensure a high rate of growth and an efficient distribution of the country's labour force. These industries may or may not employ directly a large labour force. There will, however, be important indirect and induced employment benefits because of their contribution to a buoyant economy. Such longer term benefits would not be forthcoming from industries whose participation in energy development is justified because of nationality and not economic efficiency. An important consideration in this regard is that generally higher levels of Canadian content of energy development will produce greater upward pressures on the exchange rate and on domestic prices.

Efficiency of Resource Allocation

The above reflects a more general premise, strongly advocated by the Economic Council of Canada, that an efficient use of limited resources is a basic economic imperative if Canada is to satisfy the multiplicity of social, political and economic aspirations of the society. In the Economic Council's Annual Review, *Patterns of Growth,* it has been argued that "Whatever the increase in the labour force, good growth performance must be based not only on full use of our human and other resources but also on strong gains in the efficiency with which they are used. A high rate of productivity growth is essential in the long run for increasing the standard of living of Canadians, and more generally for consistently and simultaneously achieving all our economic and social goals".

In a free enterprise system, the channelling of a country's limited resources to different sectors of the economy is primarily left to market forces. As there are some imperfections in most markets, the real and monetary assets of a country, including its labour force, are not necessarily placed where they are most efficient. In the Canadian economy, market forces could undoubtedly be more efficient in allocating different factors of production from lower earning activities to higher earning activities in response to changing patterns of supply and demand.

At the same time, governments have found it necessary to try to influence or circumvent the market processes in their effort to better direct economic development to meet the socio-economic objectives of the society. In Canada, economic development policies since Confederation have generally been oriented towards employment generation to attract immigration and support high population growth; balanced economic growth has also been an important objective and this has been most often expressed in the promotion of secondary manufacturing. To direct the host of policy instruments to meet a changing domestic and international economic climate and changing social priorities has, at different times, proved an onerous task. Moreover, the problems of economic development are, at times, complicated by stabilization policy. There frequently exists a need for policies which have im-

portant shorter-run employment and out-put punch but which may not be appropriate to an efficient pattern of economic development.

Empirical analyses of growth processes in Canada suggests that in the dynamic, open environment of our economy, the achievement of relatively high rates of growth, unlike the achievement of high employment, requires over the medium term a substantial diversion of resources in response to changing market demand and supply conditions at home and abroad. There are, however, economic and social costs associated with the reallocation of resources and such costs are not always adequately discounted in the market place. Although a number of manpower, regional development and industrial assistance programs have been implemented in the past to ease the burdens of adjustment to economic change, it remains the responsibility of government to ensure that such "opportunity" costs of economic growth be fully discounted. This does not imply that market forces leading to a reallocation of resources to more productive activities should be stifled in order to avoid the social and economic adjustments implied. Rather, the human needs of the society can be best met by removing obstacles to change and increasing the system's flexibility in order to permit the efficient allocation of our limited resources. An important consideration in this regard is that Canada has realized relatively small productivity gains in the post-war period when compared to the performance of most of our major trading partners, including the United States. This is explained in large part by rigidities and distortions in the structure of the Canadian economy.

Notwithstanding, the conceptual ease of the different proposals to alter Canada's industrial structure that were noted in previous chapters, to formulate an industrial strategy which would best direct resource allocation to the attainment of social goals requires consideration of a large number of complex interrelationships and rather crude assumptions as to future market conditions. The openness of the Canadian economy and its vulnerability to the vagaries of international markets, as well as the present uncertainties as to future payments and trade relationships, further complicate the task. The wide diversities in objectives of the different economic regions of Canada represent an important additional restraint. Not a great deal is known about the degree of regional participation in past economic growth other than that periods of sustained growth and high employment in the economy in general appear to facilitate regional economic adjustments and to alleviate regional economic problems. Conversely, the basic economic weaknesses of particular slow growth regions are more apparent in periods of stagnation.

The main questions of an industrial strategy relate to the direction and extent to which the ongoing adjustment in the system to changing patterns of demand and supply should be altered and by what policies. If it is accepted that the society is best served by strong economic growth (and there are many who do not support this view), then the direction of an industrial strategy should be towards promotion of those industries with a high productivity potential. In an open economy, this would generally mean specialization in lines of production where world markets are projected to grow rapidly, and/or where product markets are projected to experience relatively sluggish growth but marked improvements in a country's competitive position are expected. Analysis of trends in world trade suggests that in the 1970's trade in manufacturing products will continue to grow more rapidly

than trade in primary products. Within manufacturing, the high growth areas are expected to be capital machinery and equipment, transportation equipment and chemicals followed by metals and wood products. Within primary products, trade in petroleum products is expected to grow rapidly followed by trade in ores and minerals. To attempt to resist or ignore the changing pattern of world trade clearly involves the loss of output and income.

The study of demand and supply conditions for energy, which is summarized in the first section of the report, concludes that this sector of the economy has the potential to realize an impressive rate of growth in real output over the foreseeable future, particularly if world price trends for oil and natural gas continue. The willingness of corporations to place equity capital into energy projects in Canada will depend on how they view the profitability and security of such investments relative to other possible opportunities. There appear to be two major alternatives open to corporations: the first would be to not undertake further investments at all and the second would be to invest in energy development in other countries. These choices are particularly relevant for the major multinational companies which dominate the Canadian petroleum industry. This is particularly significant in the light of the very large internal fund generation of these companies. They operate throughout the world as such, having a multitude of investment opportunities. The profitability of any project to the participating companies is determined not only by the costs of bringing the product to markets and the revenue derived, but also the extent to which governments in the host country participate in this income flow through taxes, royalties, or any other form of economic rent collection.

As discussed in earlier chapters, deliberation on the economic rent issues will have to be considered in the light of the net long-term benefits that would accrue from energy development. Evaluation of these long-term benefits would have to include comparative analysis of the potential revenues from energy development and investments in other sectors of the economy.

The growth capacity of a country is limited by its own resources and its willingness and ability to rely on imported real and financial capital of other countries. An enlargement of the energy sector may restrict the growth opportunities of other sectors of the economy unless greater reliance is placed on foreign resources. The ability of energy projects to attract increasing supplies of capital and factors of production will indicate how the market views the relative rates of return among different industries. It might well be that other industries will be more successful than the energy industries in fulfilling their growth ambitions.

Past growth in this sector is explained in part by the existence of certain incentives that were not available to other sectors. It is difficult to assess the net importance of the different combinations of incentives to individual industries, but clearly the incentives to energy development that now prevail, particularly in oil and natural gas, do not appear to be required to the same extent in the high demand environment of the 1970's and 1980's.

Government will be required to intervene if it is convinced that there are social and economic costs to energy development not being fully recognized in the market. In point, the structure of the petroleum industry reflects the international oligopoly of multinational enterprises which controls free world production, trade and marketing of petroleum and products. This industry structure could

provide for a more attractive rate of return on investment over the longer term, given consideration of the relative risks involved, than might be available in a more competitive environment. An efficient method of offsetting this advantage would appear to be through collection of a greater share of the economic rent.

In summary, the issue of equitable participation by Canadians in the profits of energy development will have to be resolved. The concern that energy development may exclude development in other sectors of the economy is valid if there are not sufficient unused capital and physical resources in the economic system to fully meet the needs of large energy projects. At this stage, the *a priori* questions to be addressed relate to the existence of alternative investment opportunities and their 'social desirability' as compared to that of energy development. There are, however, no definitive answers to these questions. A decision to artificially limit development of a sector with assured demand for its products and potential high profits would appear to be justified only if more attractive alternatives could be found.

It is to be re-emphasized that the focus of the foregoing discussion relates to the impact of an energy development program. However, this is not to be construed as the only, or perhaps even the best, economic strategy for Canada. Constraints originating from policy objectives, or from physical limitations of resources, would lead to an alternative pattern of economic development whose social benefits would depend on the prevailing supply/demand forces.

SECTION V

FOREIGN OWNERSHIP AND CONTROL OF OUR ENERGY INDUSTRIES

INTRODUCTION

Foreign ownership and control of industry raise concerns in people's minds over whether Canadians are receiving the benefits they should expect from the industrial activities involved. This is particularly so in the energy industries in view of the importance of the sector, the extent of Canadian resources, the nature of world supply and demand and the high degree of foreign control over Canadian energy resources, particularly by large international companies.

Over 91% of the assets in the oil and gas industry are under foreign control. All the integrated oil companies in Canada—those active from exploration through production to refining and marketing—are foreign controlled. Foreign control of pipelines, electrical generation and uranium are considerably lower, while foreign control of coal mining has been growing in recent years.

This issue was the subject of a general review by the federal government—leading to the publication of a report on Foreign Direct Investment in Canada, and the introduction of legislation to review foreign takeovers and the investment by foreigners in new businesses.

The underlying goals of the policy reflected in this proposed legislation are:

> To see that foreign control does not frustrate Canadian objectives related to living standards and conditions and our capacity to control activities in Canada to this end;
>
> To retain and increase Canadian ownership and control where feasible and desirable.

What further policies are necessary in the energy industries depends upon what we expect of these industries and what effects we believe foreign control to have.

Chapter 1

THE EXTENT OF FOREIGN OWNERSHIP AND CONTROL

The high degree of foreign ownership and control in the Canadian energy industries makes it a focus of prime concern in the total foreign control issue. In the energy field, oil and gas are the main areas where foreign control dominates. All the integrated oil companies operating in Canada are foreign controlled. The degree of foreign control is not as extreme in coal, although it is growing. Uranium is substantially under Canadian control and electrical generation is largely under public control.

It has not been just the availability of capital that has led to high foreign ownership in the energy industries. Canadians wished to develop their resources at a rate which exceeded Canadian capacities in the areas of capital pooling, technology and management. The large integrated petroleum companies have the "know how" and resources available to carry out large scale development. Foreign governments, especially the United States, have encouraged their companies to work outside the country through beneficial tax policies and Canadian governments have been receptive to such investment. Due to the size of these firms and their high dependence on internally generated funds, a policy which seeks to affect the extent of foreign ownership and control, but which deals only with capital entering Canada will not significantly change the pattern. Moreover, the existing distribution of exploration permits would suggest a continuation of a high degree of foreign control.

Of the $31.4 billions of assets employed in the Canadian energy industries at the end of 1970, $11.0 billions or 35.1 per cent was controlled by non-residents, and $9.8 billions of this was concentrated in our petroleum industry.

Table 1 illustrates the comparative sizes of our energy industries and their relationship to the Canadian industry totals. In terms of assets, our electrical generation industry accounts for over half of the energy sector.

In each of these industries, the level of foreign ownership and control of assets in 1970 was as in Table 2.

The electrical industry is dominated by provincially-owned utilities which account for 88% of total industry assets and a similar proportion of total electricity generation.

The petroleum industry* is dominated by foreign controlled firms which account for over 91% of the assets and over 95% of the sales in the industry. Ap-

*This includes oil and gas exploration and development, refining, and distribution. For those firms whose principal activities are in the petroleum industry, all other activities are included in these data. For example, the petrochemical products of a petroleum company would be included.

TABLE 1

BALANCE SHEET OF SECTOR AND AS IT RELATES TO THE TOTAL CORPORATE ECONOMY[1]

1970 ($ Billions)

Industry	Assets	Debt	Equity
Electricity	16.0	12.4	3.6
Petroleum	10.7	3.9	6.8
Pipelines	4.1	2.8	1.3
Energy Mining	0.6	0.3	0.3
Total	31.4	19.4	12.0
Energy as a percentage of all Corporations	12.2%	11.4%	13.8%

[1]Unless otherwise specified, the data used throughout this Section are drawn from the Calura data base. The Department of Energy, Mines and Resources specified the sample as being firms with assets of over $5 million at any time during the period 1960–1970. The sample accounts for over 80% of each industry covered and, in the case of the petroleum and the electrical generation industries, for 95% of the assets of the industry. In addition, E.M.R. specified certain aggregations which differ from those found in published Calura data and are reported in this section accordingly. In this regard, three differences from published Calura data should be noted. Firstly, the non-uranium activities for firms having uranium operations have been eliminated by estimation. Secondly, the coal products industry has been eliminated from the other fossil fuels. Thirdly, Crown corporations have been added to the data in the electrical industry.

TABLE 2

FOREIGN OWNERSHIP AND CONTROL[1]

Industry	Assets ($ Millions)	Percentage Non-resident Owned	Percentage Non-resident Controlled
Electrical Industry	15,966	3.5	1.0
Petroleum (Oil and Gas)	10,725	76.8	91.3
Petroleum Transportation (basically pipelines)	4,108	21.8	18.7
Coal Mining	Confidential[2]	60.3	73.2
Uranium	Confidential[2]	24.3	22.5

[1]Non-resident Ownership is the per cent of total employed in the industry which is owned by non-residents. Non-resident Control is the per cent of total assets which come under the control of non-residents through non-resident ownership of over 50% of the equity capital of a firm.

[2]Prohibitions on the disclosure of statistical aggregates covering only a few firms prevent the inclusion of these data.

proximately four-fifths of the non-resident controlled assets are held by U.S. residents or U.S. resident controlled corporations. Of the firms which have operations in all phases of this industry—from exploration to marketing—non-resident control is 100%. This group of "integrated" companies accounts for $5.5 billions or 51% of the total industry assets.

Approximately 20% of the petroleum transportation industry, which is composed mainly of oil and gas pipelines, is non-resident owned and controlled. By and large the activities of this sector come under government regulation.

The current level of foreign control in the coal industry (73% of assets) reflects recent developments in western export-oriented metallurgical coal development. The eastern thermal coal industry has largely come under public control.

The uranium industry has a mix of public and private ownership, with over 20% of the assets under foreign control at the present time.

For greater details of the proportions of equity, sales and book profits under non-resident ownership and control, as well as for details of the development of this foreign participation over the 1960-1970 period the reader can refer to Appendix B.

The Growth of Foreign Ownership and Control

The position of foreign ownership in the energy sector revolves largely around the foreign participation in the petroleum industry. The petroleum industry represents approximately one-third of the total assets involved in the energy area.

Excluding the electrical generation industry (in which Canadian ownership is high), the petroleum industry represents 70% of the remaining energy industries. As noted earlier, foreign ownership and control in this sector is the highest of the energy industries and accounts for approximately 88% of the foreign controlled assets in the entire energy sector. For these reasons, most of the following discussion will focus on the petroleum industry.

Some general notion of the financing of investment in the petroleum industry is shown in Tables 3 and 4.

The most important source of funds for the petroleum industry is internal cash generation. For the years 1961-1970, 66% of the capital came from internal sources. Of the sources external to the firm 30% was drawn from Canadian sources. Approximately 23% of the total financing was derived from foreign sources for the decade—and less than 20% for the 1966-70 period. For the integrated companies (which are 100% foreign controlled) internal capital sources tend to account for an even larger proportion of total capital than for the industry as a whole.

While the relative importance of each source may well change, in the future growth of this industry a policy which deals only with capital entering Canada will not significantly change the ownership pattern nor cover what could be the largest source of capital for the growth of foreign controlled investment in Canada.

In 1969, for the total economy the net direct investment inflow by non-residents into Canada was $720 million. Of that net inflow, $144 million, or 20% of the total was accounted for by the petroleum industry alone.

Foreign investment in Canada can grow through the expansion of existing foreign investments, the undertaking of new investment projects by foreigners and the acquisition by foreigners of Canadian controlled businesses.

While the reasons for the growth of a firm are potentially myriad—and lie beyond the scope of this document—economies of scale would appear to have played an important part in the growth of firms in the petroleum industry. Within

TABLE 3

SOURCES AND APPLICATIONS OF FUNDS 1961–1970
PETROLEUM INDUSTRY
($ thousands)

	Foreign Controlled Companies						Canadian Controlled Companies					
Sources of Funds	1961–1965	%	1966–1970	%	1961–1970	%	1961–1965	%	1966–1970	%	1961–1970	%
Internal Sources												
Book Profit	1,120,407	25.9	2,277,492	35.4	3,397,899	31.5	77,918	27.6	146,959	23.6	224,877	24.8
Depreciation	712,198	16.4	948,617	14.7	1,660,815	15.4	35,634	12.6	49,480	7.9	85,114	9.4
Depletion and Amortization	410,952	9.5	724,287	11.2	1,135,239	10.5	32,234	11.4	59,688	9.6	91,922	10.2
Deferred Taxes	21,654	.5	279,831	4.3	301,485	2.8	14,217	5.0	33,378	5.4	47,595	5.2
Deferred Charge Decrease	20,360	.5	17,718	.3	38,078	.4	2,006	0.7	363	0.1	2,369	0.3
Other	206,044	4.8	511,974	7.9	718,018	6.7	24,170	8.6	33,818	5.4	57,988	6.4
Total Internal Percentage— Total Internal Sources	2,491,615	57.6	4,759,919	73.8	7,251,534	67.3	186,179	66.0	323,686	52.0	509,865	56.3
External Sources												
Equity Increase	952,932	22.0	1,480,598	23.0	2,433,530	22.5	39,621	14.0	214,807	34.5	254,428	28.1
Increases from Affiliates	125,117	2.9	(107,031)	(1.7)	18,086	.2	8,486	3.0	21,518	3.5	30,004	3.3
Net Increase Long Term Debt	330,588	7.6	389,362	6.0	719,950	6.7	47,663	16.9	1,578	0.3	49,241	5.4
Other Long Term Debt	185,014	4.3	(511,177)	(7.9)	(326,163)	(3.0)	(17,473)	(6.2)	5,829	0.9	(11,644)	(1.3)
Increased Bank Loans	8,015	.2	26,586	.4	34,601	.3	(9,945)	(3.5)	19,385	3.1	9,440	1.0
Increased Short Term Debt	4,806	.1	58,531	.9	63,337	.6	(13,658)	(4.8)	867	0.1	(12,791)	(1.4)
Other Short Term Debt	226,777	5.3	353,931	5.5	580,708	5.4	41,341	14.6	35,154	5.6	76,495	8.5
Total External Percentage— Total External Sources	1,833,259	42.4	1,690,800	26.2	3,524,059	32.7	96,035	34.0	299,138	48.0	395,173	43.7
Total Sources	4,324,874	100.0	6,450,719	100.0	10,775,593	100.0	282,214	100.0	622,824	100.0	905,038	100.0

Application of Funds												
Dividends & Transfers to Head Office	485,872	11.2	1,165,612	18.1	1,651,484	15.3	20,297	7.2	57,023	9.1	77,320	8.5
Fixed Capital Additions	2,694,371	62.3	4,039,767	62.6	6,734,138	62.5	196,420	69.6	285,082	45.8	481,502	53.2
Long Term Investments	6,161	.1	2,788	.0	8,949	.1	10,553	3.7	(43,577)	(7.0)	(33,024)	(3.6)
Investments in Affiliates	566,825	13.1	271,647	4.2	838,472	7.8	51,411	18.2	216,985	34.8	268,396	29.7
Deferred Charge Increase	89,267	2.1	65,352	1.0	154,619	1.4	1,402	0.5	6,709	1.1	8,111	0.9
Other Long Term	69,468	1.6	216,265	3.4	285,733	2.7	(20,409)	(7.2)	54,060	8.7	33,651	3.7
Increased Inventories	55,604	1.3	114,685	1.8	170,289	1.6	(816)	(0.3)	4,707	0.8	3,891	0.4
Other Short Term	357,306	8.3	574,603	8.9	931,909	8.6	23,356	8.3	41,835	6.7	65,191	7.2
Total Applications	4,324,874	100.0	6,450,719	100.0	10,775,593	100.0	282,214	100.0	622,824	100.0	905,038	100.0

TABLE 4

NATIONALITY OF EXTERNAL SOURCES OF FUNDS
PETROLEUM INDUSTRY
($ thousands)

	Foreign Controlled Companies						Canadian Controlled Companies					
	1961–1965	%	1966–1970	%	1961–1970	%	1961–1965	%	1966–1970	%	1961–1970	%
Canadian												
Equity Increase	92,935	5.1	275,901	16.3	368,836	10.5	36,302	37.8	152,611	51.0	188,913	47.8
Increase from Affiliates	(58,960)	(3.3)	52,829	3.1	(6,131)	(0.2)	9,390	9.8	19,663	6.6	29,053	7.3
Net Increase—												
Long Term Debt	244,635	13.2	288,128	17.0	532,763	15.1	36,223	37.7	1,199	0.4	37,422	9.5
Other Long Term Debt	185,014	10.1	(511,177)	(30.2)	(326,163)	(9.3)	(17,473)	(18.2)	5,829	1.9	(11,644)	(2.9)
Increased Bank Loans	6,453	0.4	24,756	1.5	31,209	0.9	(10,167)	(10.6)	19,077	6.4	8,910	2.3
Increased Short Term Debt	4,746	0.3	55,394	3.3	60,140	1.7	(13,196)	(13.7)	845	0.3	(12,351)	(3.1)
Other Short Term Debt	226,777	12.5	353,931	20.9	580,708	16.5	41,341	43.0	35,154	11.8	76,495	19.3
Total Canadian	701,600	38.3	539,762	31.9	1,241,362	35.2	82,420	85.8	234,378	78.4	316,798	80.2
Foreign												
Equity Increase	860,007	46.9	1,204,697	71.3	2,064,704	58.6	3,319	3.5	62,196	20.8	65,515	16.6
Increase from Affiliates	184,077	10.0	(159,860)	(9.5)	24,217	0.7	(904)	(1.0)	1,855	0.6	951	0.2
Net Increase—												
Long Term Debt	85,953	4.7	101,234	6.0	187,187	5.3	11,440	11.9	379	0.1	11,819	3.0
Other Long Term Debt*												
Increased Bank Loans	1,562	0.1	1,831	0.1	3,393	0.1	222	0.2	308	0.1	530	0.1
Increased Short Term Debt	60	0.0	3,137	0.2	3,197	0.1	(462)	(0.4)	22	0.0	(440)	(0.1)
Other Short Term Debt*												
Total Foreign	1,131,659	61.7	1,151,038	68.1	2,282,697	64.8	13,615	14.2	64,760	21.6	78,375	19.8
Total External Sources	1,833,259	100.0	1,690,800	100.0	3,524,059	100.0	96,035	100.0	299,138	100.0	395,173	100.0

*Assumed to be Canadian.

an enterprise vertical integration of exploration, development, production, refining and marketing activities appears to have involved substantial advantages for the large firms. Indeed, 9.2% of the companies in the industry account for 94.7% of the assets and the totally integrated group of companies accounts for $5.5 billions of assets or just over 50% of the total industry assets.

The assets employed by oil and gas companies which were Canadian-controlled in 1970 totalled $844 million, or 7.9% of total industry assets. This had grown by 151% from the $366 millions total in 1960. In contrast, the sales of the Canadian-controlled group increased by only 89% during the period and their relative share declined from 4.7% in 1960 to 4% in 1970. This relative decline in Canadian-controlled as compared to foreign-controlled firms' share of sales is largely due to companies leaving the Canadian-controlled group as the result of foreign takeovers. (By comparison, the growth rate of the total petroleum industry in the period 1960-1970 was 134% in assets and 121% in sales.)

Within the petroleum industry the economic behaviour of different groups of firms varied widely. Growth of groups within the industry is shown in Table 5.

TABLE 5

PETROLEUM SUB-INDUSTRIES' GROWTH 1960 - 1970[1]

Group	Percent of growth above 1960 level	
	Assets	Sales
A. Fully integrated Firms	100	100
B. Semi-integrated Firms	142	107
C. Non-integrated Firms (Includes D)	209	306
D. Companies which in 1969 were Canadian-controlled	194	77
The Petroleum Industry Aggregate	134	121

[1] For comparative purposes an aggregate of the Canadian corporate sector of 4,000 companies (excluding Crown corporations) grew by 100% of assets and 103% of sales. (The higher relative growth rates for the smaller firms does not negate the previously discussed economies of scale as they are technically unrelated concepts.)

The major comparison to be made is between the non-integrated firms (Group C) and the Canadian-controlled companies (Group D). These are reasonably homogeneous in that they represent a comparable phase of development and the differential rate of growth in sales (versus their similar asset growth) is principally explainable by the impact of foreign acquisition of Canadian assets at the point when these firms begin to sell their products (turn over their assets). The sales that might have been developed by the Canadian-controlled firms shift to foreign control by reason of takeovers at this point in their development. Both past and present market conditions allowed equal access to markets to both groups so that the difference would not reflect a different selling opportunity based upon their asset base.

The foreign takeover of Canadian-controlled firms has accounted for the transfer of $253.6 million of assets as at the date of acquistion. These assets have, of course, grown subsequent to the takeover and account for a total book value of $572.8 million in 1970 or 5.8% of the total assets held by the foreign controlled firms, using their observed growth rate after acquisition for this purpose. Some of this growth is a reflection of the infusion of new capital and the purchase of new assets.

The purchaser has often been an integrated company and able to fit the acquired assets into an integrated enterprise. There are, of course, no Canadian integrated companies in this industry. This growth of foreign investment through takeovers undoubtedly reflects in part the advantages to the acquiring firms of vertical integration and scale of operations which the integrated firms can offer. Other motives or advantages such as the extension of market and outlets for crude and the dominance in certain markets for the purchaser can be seen. Similarly, the seller has, in some instances, been at a disadvantage due to his not having ready or reliable access to product, or refining capacity from competitive sources in the case of marketers; and an inadequacy of capital to develop reserves in the case of producers. These transactions are often financed through "share swaps" whereby the seller accepts shares in the purchasing company in return for the sale of his interest. Little or no cash may be involved but the acquired firm's assets can then be integrated into the larger organization and the seller, in a sense, advances the purchaser the use of the assets in return for a share in the future value of the larger operation.

Current expectations are that the next several years will be a period of high demand for energy products and for the exploration and development of more energy resources in Canada. Most territory which is expected to yield new oil and gas reserves is already under permit to firms doing exploration. If one examines the present distribution of these federal and provincial permits and leases it can be determined that Canadian-controlled firms only hold the rights to about 15%. Even though the areas where petroleum will ultimately be discovered will establish the eventual degree of Canadian control, it is obvious that unless significant changes occur at the production lease stage, the degree of foreign control in the production area of this industry can be expected to continue.

What Has Determined the Level of Foreign Ownership?

The level of foreign investment in the energy sector of the economy has been shown to be high. The reasons for this are both numerous and varied.

To begin with, the Canadian environment has been receptive to such investments. The growth aspirations of Canadians have frequently exceeded the then existing capacity of Canadian capital, technology and management. These "gaps" in Canadian capacities have often been filled by foreign investment—and frequently by controlling investment of a foreign firm in a Canadian subsidiary operation.

In resource projects, the need for large pools of capital for a single project would have been a strain on Canadian financial institutions. The assurance of the large markets for a secure investment and for the realization of economies of scale in exploration, development and production has been an important influence on

foreign control in some resource projects—but probably less critical in the energy field due to the demand for energy, particularly in the presence of policies such as the national oil policy.

Foreign firms had the technology and other "know-how" to undertake energy projects promptly and the size and diversification to assume the business risks involved in exploration. These firms were also interested in maintaining or advancing their world position in petroleum and their presence in Canada in refining and distribution. Their operations in Canada could be very similar to their activities in the United States due to the similarities in the attitudes, tastes, living standards and technology and the proximity for U.S. companies in particular made surveillance reasonably easy.

The desire of Canadians for development, despite limits on Canadian capacities, led Canadian governments, both federal and provincial, to generate a framework through tax benefits and the provision of a supporting infrastructure which would be made available to all investors regardless of nationality. Heavy reliance on imports of petroleum was not desirable. If the resources could be found in Canada, for Canadian needs at least, their development would also reduce the deficit on the current account of the balance of payments. Export development would further enhance the rate of development and strengthen the Canadian international payments position. The receptiveness of Canadian public policy was matched by the stability, politically and economically, of Canada and by the high level of development and skills in Canada which supports business activities.

Foreign firms were in a position to take advantage of these opportunities and incentives. The export market opportunities in the U.S. in particular may also have encouraged American investment. Foreign governments, particularly the U.S. government, did nothing to discourage and much to support these foreign developments by their firms. Tax policies in the United States for example, have supported foreign investment. U.S. capital markets and the firms themselves were able to provide a large part of the necessary financing.

More than just the relative availability of capital, therefore, accounts for foreign control of many Canadian energy industry firms. A variety of industrial factors and governmental policies combine to account for the present patterns. The market dominance achieved by many of the foreign firms makes it difficult for smaller and newer firms to gain a foothold. The large capital costs essential to any significant presence in these industries makes entry by a new Canadian enterprise difficult. The vertically integrated structure of the largest firms in the petroleum industry permits them a kind of flexibility of access to capital reserves which a less integrated Canadian firm would have great difficulty challenging. The national oil policy which divided Canada into two marketing regions also affected the capacity of independent non-integrated firms to compete.

Chapter 2

IMPACT OF FOREIGN CONTROL

Foreign control of Canadian energy industries can affect several aspects of their performance. The rate of development of the energy sector would likely have been slower without the capital, technology and entrepreneurship of foreign firms. The realization of optimal benefits for Canada from these activities is what is at issue. While the impact of foreign control in several areas cannot be isolated, the items of concern which must be considered include the following:

Since much in the international trade is on a non-arms-length basis, profits in Canada, and consequent tax revenues can be adversely affected;

Foreign controlled firms may be less inclined than a comparable Canadian controlled firm to process the energy resources in Canada, less inclined to undertake research and development in Canada, more inclined to import goods and services, and more inclined to employ foreigners in senior management positions;

The domination of foreign controlled enterprises could also affect the structure and concentration of the industry in Canada;

To the extent that foreign control involves more and different international transactions and remittances than a Canadian-controlled project, the balance of payments impact over the life of a project would differ from a comparable Canadian-controlled venture.

The full impact of foreign control cannot be reduced to a single measure since it involves both advantages and disadvantages, which factors may be difficult to quantify, and which include both economic and non-economic elements. The realization of optimum results according to Canadian goals is the objective for public policy.

A principal problem of foreign control of the Canadian energy industries is whether Canada is getting the desired benefits from the exploitation of these resources. Does the high level of foreign ownership and control of energy resources in Canada reduce the realization of benefits in Canada? Does this level of foreign participation make the realization of Canadian objectives for resource development more difficult? Does this level of foreign participation alter or limit in any way the variety of government techniques which might be appropriate to the realization of Canadian objectives?

The following sections explore areas where foreign investment might impose some constraints. In many instances there are no data on which to draw con-

clusions as to the performance and impact of foreign controlled firms. The discussion is often inconclusive as a result.

Development of Energy Resources

Some of the developments which have taken place under foreign control might well have been undertaken by Canadian investment and entrepreneurship under the incentives of international market demand and prices. It is highly likely, however, that the rate of development of many sectors of the Canadian economy would have been less rapid without the direct involvement of foreign capital, technology and entrepreneurship. It is also probable that the level of natural resource extraction in Canada relative to other activities in the economy is higher than would have been the case in the absence of foreign investment.

In the presence of large export markets, a firm Canadian policy insisting on Canadian control might have led to the development of many projects with the assistance of foreign debt financing, long-term sales contracts and other arms-length relationships between the Canadian operation and the foreign purchaser. At the same time, other projects would not have been undertaken—or perhaps not undertaken until a significantly later date—if foreign control had not been permitted in the case of such projects. This would have depended in large part on the alternative sources of supply available to the users and the relative prices of such energy sources.

It is not of course possible at this date to quantify the extent to which the rate of development of Canadian energy resources would have proceeded under a variety of different assumptions. It is clear, however, that both federal and provincial governments in Canada have supported and encouraged the kind of development which energy projects have involved. Should these governments, in the future, wish to reduce the rate of development which is dictated by domestic and international market forces, there are a variety of opportunities for governments to do so. While the prohibition of foreign control of such projects would, perhaps, have some effect on this rate, the reduction involved would be uncertain as to its total amount and haphazard as to its location of impact.

Exports of Energy and Energy Products

The foreign investor in natural resource products is often seeking raw material inputs from secure sources of supply and at competitive costs. In the case of many mineral commodities the investor may be seeking to supply his processing and fabricating facilities in his home market. This may reduce his inclination to pursue the fullest viable level of processing and fabrication in Canada prior to export.

The situation would not, however, appear to be as significant in the case of energy developments since the potential for processing energy whose intended use is as an energy source is limited.

Oil Trade: In the exploration and production sectors of the crude oil and natural gas industry, ownership is quite similar, with a substantial proportion of production being controlled by multinational companies. A significant difference does appear, however, in the transportation and distribution sectors where, in the case of natural

gas, non-integrated independent companies and government-owned utilities are more common. In oil, the transportation, refining and marketing are more vertically integrated within large firms—and are dominated by foreign controlled enterprises. For example, only 1.7 per cent of the refining capacity in Canada is not under foreign control, and most of the foreign controlled refining is operated by totally integrated companies.

Ownership of Canadian crude oil production is widely dispersed as Table 1 indicates:

TABLE 1

ESTIMATED CANADIAN PRODUCTION OF CRUDE OIL AND GAS LIQUIDS
13 PRODUCERS—1971

(In thousands of barrels per day)

	Volume	Percentage
Imperial Oil	213.0	14
Texaco (estimated)	124.0	8
Mobil	102.0	7
Gulf Canada	100.0	6
Shell	79.0	5
Chevron	79.0	5
Amoco	60.0	4
HBOG	62.0	4
Pacific	53.0	3
Husky	38	2
Pan Canadian	26	2
Aquitane	22	1
Home	21	1
Others	605.3	38
Total	1,584.3	100

SOURCE: *Canadian Oil Register*

For all intents and purposes foreign purchasers of Canadian crude oil pay the posted price plus freight to destination. Posted prices in Canada are set at Edmonton and the price setting mechanism is basically price leadership by the majors. The prices are such as to make the product competitive when laid down in the Chicago market. Refineries located between Edmonton and Chicago (including northern U.S. facilities) receive crude at prices reflecting the lower transportation cost and are, therefore, less than prices in Chicago.

In determining the posted price, the majors must consider a variety of factors: a price which will permit penetration of the Chicago market to achieve substantial export volumes; a price sufficiently low to allow an adequate refining return to western refineries owned by these majors when processing Canadian crude which

they purchased at the posted price (all majors are net purchasers of crude west of the N.O.P. line); the extent to which U.S. refineries supplied at the posted price are affiliated companies; and the competitiveness of the heavy fuel oils which can move over the N.O.P. line (mainly into B.C. and Ontario). These tend to provide downward pressures on posted prices.

To the extent that U.S. prices—particularly those in the Chicago market—influence Canadian posted prices, the degree of foreign control of production and the multinational structure of the firms would not appear to significantly affect Canadian crude prices except to the extent that they do so through influencing United States domestic prices.

Recent Canadian controls on crude exports will provide a public authority determination of both the export volumes and prices.

On the question of further processing of oil, it is important to note that most of the world's oil moves in crude form by tanker or pipeline with little or no prior processing. Refining has been basically a market-oriented activity and is located as near as possible to consuming centres.

All of the oil sold in export markets from Canada goes to the United States and virtually all of it is in crude form—with some co-mingling with natural gas liquids. The United States in the past levied an import duty on crude imports of 5¼ cents per barrel on Canadian crude testing under 25 degrees API gravity and 10½ cents at or above that gravity. In addition, there have been quotas on imports of Canadian crude into the United States. Refined products attracted a higher tariff—but present levels did not constitute significant barriers to these exports to the U.S. The whole duty and quota licence system has been replaced by a licence-fee quota system taking effect on 1 May 1973.

Given the expected high level of U.S. demand and the resulting opportunity for threshold volumes for transporting refined product it might be possible to export a considerable volume of refined product. It is possible that the degree of foreign control in this industry, and the extent of international integration has and could continue to retard this development, since the firms involved have existing refining capacity in the U.S. markets served presently by Canadian crude. The desirability of exporting refined products in place of crude oil requires separate assessment as to the economic benefits and environmental factors.

Canada generally processes crude for its own needs and does not put any tariff on the import of crude.

In 1971 the price for imported crude averaged $2.21 per barrel (fob point of origin)—substantially lower than the average price for Canadian crudes which were at $2.84. International crude imported into Canada is largely from affiliates of the importer (80-90% of total Canadian imports) so that prices are determined in a non-arms-length relationship. This practice is widespread in the international oil industry.

The largest part of the imports are in crude form—although some refined product (approximately 20% of total value of imports in 1971) are imported. Some of the crude imported in the future will be for purposes of refining and re-export, mainly to the U.S. market.

Natural Gas Trade: The marketing channel for exported gas includes the transmission and distribution functions performed under conditions of long-term con-

tracts. A Canadian incorporated transmission company buys the gas from the producers and transports the purchased gas to the border, reselling it to an American transmission company. In turn, the latter resells it in the U.S. to distribution companies for delivery to customers in their market areas. In some cases a single American company will perform both transmission and distribution functions in the U.S. The purchase of the gas at the wellhead is not regulated and is negotiated at an arms-length basis.

The export sales of natural gas are largely on a non-arms length basis due to the interconnected ownership between the Canadian and American companies concerned. Over 80 per cent of the gas exports are between transmissioin companies with some degree of affiliation. The contractual arrangements are however regulated; the N.E.B. controls the export volumes and border price and the F.P.C. controls the import volumes and price.

It is in Canada's interest to obtain a fair price for the exported gas. Such a price should reflect the economic value in the market place in relation to least cost alternative supplies of energy. Historically each new export licence has reflected this criterion at the time the licence was issued. However, as a result of the U.S. energy shortage, Canadian export prices for gas presently fall short of this goal. The adjustment of export prices is complicated by the long-term nature of the contracts. The contracts by and large contain price adjustment clauses related to the cost of service (including the cost of gas), but are not yet fully responsive to changes in market condition in the U.S. This problem and its possible resolution bears little relationship to the degree or nature of the interlocking ownership of the exporting and importing transmission companies.

It is obvious that any policy of increasing the export price of Canadian natural gas by raising the individual contract prices must, to be effective, be matched by approvals of the regulatory agencies in the United States. The most recent increases in border prices under existing contracts have not been entirely voluntary, but reflect the realities of present federal and provincial policies and the suasion exerted by the N.E.B. The existence of a degree of affiliation between the companies involved has reduced possible opposition by the purchasing company and thus expedited the application for the necessary approvals from the U.S. regulatory agencies.

The upstream benefits to the industry and to the economy resulting from increased export revenues will undoubtedly provide more funds which could be used for exploration and development as well as increasing royalties, taxes, and associated revenues. However, any assessment of those benefits must include an evaluation of the degree of upward pressure that the increased export price will exert on domestic gas prices.

It follows therefore that the future regulatory considerations should go beyond the adequacy of the export price alone. The level of foreign ownership raises the question of the share of the increase received by the federal and provincial governments, by the producer and by the transmission company—as well as the ultimate disposition of the proceeds gained by foreign-owned firms.

It is important to consider whether the further processing of natural gas through such uses as a feedstock to the petrochemical industry is impeded to any extent by the level of foreign ownership and/or the degree of international inte-

gration of Canadian producing companies. It has been noted that there are several cost factors and market density considerations, as well as trade barriers, which contribute to the economic difficulties faced by any firm seeking to develop such activities in Canada. The structure of several of these industries and its present location of plants is a reflection of a variety of influences over the past decade and represents a pattern which involves sunk costs in existing plant facilities and marketing patterns for the present operators. In some of these industries the degree of concentration, and often market power which exists in the hands of many multinational enterprises, supports the perpetuation of such a structure and permits a reduced degree of responsiveness to real underlying costs or to governmental attempts to influence the location of further processing or manufacturing facilities. Since the level of foreign ownership in some of these petrochemical industries in Canada is closely related to the concentrated structure of these industries—that is, the presence of the multinational firms and their dominant position in the Canadian industry—it is virtually impossible to isolate the extent to which foreign control as distinct from industrial structure and other trade barrier and cost influences account for the prevailing structure.

In the absence of foreign investment and control of these industries, however, it is possible that a less rigid industrial structure might exist—but it is an open question as to whether Canadian producers would be able to achieve economies of scale in their production and competitive access to export markets for more highly processed or finished goods.

More importantly in the context of this section, if it is desirable for the government to attempt to increase the extent of processing and manufacturing in Canada based on energy product feedstocks, it is not clear that the restriction of foreign investment is the best technique since Canadian controlled firms might be no more inclined, if they operate internationally, to locate such facilities in Canada, and since the restriction of foreign investment might involve the foregoing of other advantages of economic development which it might offer.

Electrical Energy Trade: The majority of major electric utilities in Canada are owned by provincial governments. Of all the electricity generated by utilities in Canada in 1971, 88.5 per cent was produced by government owned utilities.

Industrial generation of electric energy in 1962 was 21% of the total electric energy produced in Canada, however, the proportion of industrial generation has been declining steadily in recent years, and in 1970 amounted to 16% of the total electric energy produced in Canada.

The purpose of the international interconnections of certain electrical systems of Canada and the United States is primarily that of energy exchange with associated system operational benefits. In some cases these interconnections have also provided mutual support to the interconnected systems under emergency conditions. While the public utilities of neither country are dependent upon electrical supply from the other country, there are some individual cases of comparatively small industrial operations, e.g. two paper mills in the United States, relying on imported power.

Since World War II, exports have run in range of 2% to 6% of total Canadian generation and in many years this has been balanced by imports. In some years there has been a net import. In 1972 exports increased greatly but the excess of

exports over imports, expressed as a percentage of the total Canadian generation only grew from 0.7% in 1969 to 3.3% in 1972.

Reflecting the predominance of public ownership of utilities in Canada, less than 10% of Canadian exports of power are to affiliated companies in the U.S. As export prices are directly regulated by the N.E.B., it does not appear that there are deviations from arms-length pricing even in the small proportion of cases of exports to affiliated companies.

Coal Trade: Although Canada exported 9.4 million short tons of coal in 1972 (5.5 times the export of 1.4 million tons in 1969), and produced 20.6 million tons (a 100% increase over 1969) we imported 19.3 million tons at an estimated cost of $230 million. It is significant that the majority of our future export contracts are with Japan while Ontario is, for all intents and purposes, entirely dependent upon imports of U.S. coal for steelmaking and thermal generation plants.

Shipments to Japan account for nearly all exports at present. These transactions are technically arms-length exports although there are some long term and financing links between the buyers and sellers.

Total coal imports to Canada are primarily based on long-term contracts; 23% was from Canadian controlled mines in the United States owned by Canadian steel producers. The captive mines provided 52% of the Canadian steel industry's 7.4 million ton requirement for 1972 and may be considered as non-arms-length transactions.

Uranium Trade: During the 1950's, uranium was one of Canada's major energy exports, primarily because of its utilization for military programs abroad. All exports were of an arms-length nature. Beginning in the 1960's demand began to develop for the peaceful utilization of uranium in nuclear power reactors. Consequently, a policy was announced by the Minister of Energy, Mines and Resources in June, 1969, to ensure inter alia that uranium exports would be in the public interest. Included in this policy is provision for consideration of the buyer-seller relationship and the adequacy of the sale price. This policy is administered by the Atomic Energy Control Board acting under the authority of the Atomic Energy Control Act.

Procurement of Goods and Services

Foreign controlled firms in general have a greater propensity than Canadian controlled firms to rely on imports for the various inputs necessary to their operations. The same tendency has been observed in some instances in the procurement of services. In the energy sector this might be particularly significant with regard to consulting services in the engineering or other technical fields, geological survey and other contractor work. Foreign investors and businessmen might prefer to have the report and opinion of a firm with which they have had experience rather than relying on a lesser-known Canadian service firm.

The data available for the petroleum sector do not differentiate petroleum and petroleum products from other imports of goods and services. The figures are heavily dominated by imports of petroleum and petroleum products that in large part is the result of the National Oil Policy. As a result, no conclusions on this aspect of the performance of foreign owned firms can be drawn from available information.

While data is not readily available on the different patterns of procurement practices by foreign owned firms in the case of the purchases of services and the purchases of machinery and other commodities, there could likely be some relationship between any propensity to rely on foreign technical and engineering services and the purchase of machinery and equipment from similar foreign sources. A foreign engineer might be expected to be better informed about goods available in his home economy, and manufacturers in those regions might be more likely to meet the specifications that are common ground between the technical service industry and the suppliers.

It is, of course, necessary to determine whether, in particular circumstances, any propensity to import goods and services is a reflection of economies of scale or other cost determinants or whether the Canadian market could be made to supply these inputs on a competitive basis. Whether the Canadian subsidiaries are free to import from the lowest cost sources and whether these firms provide an adequate opportunity for Canadian suppliers are the important considerations in assessing the impact of foreign control in this sector. Failure to do so would mean that the Canadian subsidiary is obliged to absorb higher costs in the interest of the global development of the firm, the development of Canadian industrial and technical capacities is retarded and the level of activity in Canada is lower than it might otherwise be in these areas.

The Hiring of Canadians

Foreign owned petroleum companies have tended to involve Canadians as both officers and directors in their Canadian subsidiaries. The integrated petroleum companies—all of which are foreign controlled—listed 75.8% of their officers and directors as Canadian citizens in 1970. This had increased from 65.1% in 1962 and 72.4% in 1966.

The figures for the foreign controlled energy sector in total are somewhat lower, at approximately 60% of the total.

Foreign managerial inputs by direct appointment of personnel to the subsidiary, and by head office services and systems, can improve the skills available for the efficient administration of Canadian subsidiaries. Furthermore, Canadian personnel can acquire improved skills and opportunities.

The information which is based upon the entire sector, or even a collection of companies such as the integrated petroleum companies, masks what might well be significant variations from one company to another. More importantly in this industry, however, is the fact that the significance of the decisions and other responsibilities carried by the officers and directors of the Canadian company must be seen in the context of the international nature of many of the foreign controlled firms which operate in this industry. Without intending to disparage the role of the management of Canadian subsidiaries, this area of the economy is highly integrated into international activity so that Canadian managerial participation, while training Canadians and offering worthwhile employment opportunities, may not do as much for the "Canadianization" of decisions and operations of these companies.

Nevertheless, Canadian personnel can bring a greater awareness of Canadian conditions and opportunities to the firm. As noted early in relation to procurement, if the person making procurement decisions is not familiar with the availability and

competitiveness of Canadian goods or services, he would be expected to favour the foreign sources with which he is familiar and in which he has some confidence.

Foreign control does involve a degree of important business decision-making at the foreign head office. This is inherently part of the rationale for foreign investment. While the management of a subsidiary will influence head office management, there is ultimately a perspective of the global firm and a consideration of factors beyond the information likely available to the subsidiary management which must direct the most important strategy decisions of a foreign-controlled firm in Canada. This can mean that the result of decisions affecting the Canadian operations might be less than is possible when viewed from the interests of the Canadian business unit alone.

Research and Development

Research and Development expenditures in the mineral industry in general in Canada have been lower than in many other countries. The high degree of foreign control is probably a contributing factor. The Statistics Canada data for 1970 show that the "oil and gas wells and petroleum products" groups together spent $18.1 million for current research and development. Of the $18.1 million, the petroleum products group reporting spent $16.0 million and the "oil and gas wells" only $2.1 million. The latter group is mostly the junior firms of the petroleum industry: the large-scale integrated firms which are virtually all foreign controlled, are grouped in the "petroleum products" industry which in 1967 spent $15.9 million and in 1969 spent $19.8 million on current research and development. The integrated firms of the petroleum industry had, in 1970, sales of close to $4 billion so that their current R&D spending of $16 millions was about 0.4% of sales.

Much of the research and development work which is undertaken in Canada by foreign owned firms is integrated into its enterprise-wide program for R&D. As a result, it would be less likely to relate directly to product innovation and development in Canada for purposes of production leading to exports of improved products. Some of the work would, of course, relate to the development of products appropriate to the occasionally unique characteristics of Canadian market needs. There is no ready measure available of the nature of the R&D work done in Canada. The expenditures shown could relate to activities varying from the simple gathering of data to the actual experimentation, assessment and product innovation work.

This information would suggest that technological advances made elsewhere in the foreign owned company would be moved into Canada with the Canadian subsidiary likely paying a royalty or other form of fee for the access.

In the 1967-1971 period, the companies reporting to the Department of Industry, Trade and Commerce spent $81 million on the purchase of technology, e.g., patent rights—but only 67% of that amount was spent in Canada. The remainder was spent on acquiring technology from petroleum companies abroad.

Tax and Other Public Revenues

Tax revenues, royalties, lease payments and other payments by energy companies to governments in Canada can constitute a significant advantage to Canada from

the development of these resources. Fiscal terms set down by government are an important instrument for the capturing of economic benefits in Canada.

It is not possible from available data to detect any significant differences between foreign and Canadian controlled firms with respect to tax revenues—or at least no differences readily attributable to the fact of foreign or Canadian control.

Incomes taxes, payable as they are on profits after allowable expenses, depend very greatly on the level and nature of those expenses. Foreign owned companies in Canada can have fairly widely varying profit levels by the charges imposed on the Canadian subsidiary for management services by the parent, royalties and other fees, and the prices charged for the sale of goods to the Canadian affiliate or the purchase of commodities from the Canadian subsidiary. A fairly small shift in the prices put on these transactions can effect a fairly major adjustment to taxable profit levels. The non-arms-length nature of a fairly high proportion of the transactions undertaken by foreign controlled firms increases the potential for such transfers to be disadvantageous to the tax receipts of the Canadian government. This aspect of concern is, however, more properly a matter for tax policy and is, in fact, dealt with by various provisions of the existing tax laws of the country.

Industrial Structure and Competition

The number of firms accounting for the output of an industry, i.e., its concentration, can significantly affect the degree of competition and the resulting performance of those firms in terms of efficiency, levels of output, and prices to the consuming public.

The petroleum industry is highly concentrated. The eight largest firms in the industry accounted for over 80% of the sales of that industry in 1968. The degree of concentration varies considerably, however, over the various stages of activity. Refining, for example, is very highly concentrated; marketing and the manufacturing of petroleum and coal products are quite highly concentrated; while the production of crude oil and natural gas are not highly concentrated.

The level of concentration and the degree of foreign ownership are correlated. Industries in which foreign ownership and control is high tend to be more highly concentrated than those in which foreign ownership and control is low. In addition, the most dominant firms in these industries tend to be the foreign controlled firms. In the petroleum industry, for example, the average assets of firms controlled by non-residents is $97.3 million while the average assets of the firms controlled by residents is $49.6 million.[1]

The size, market dominance, and international structure of the firms in many of the energy industries is particularly important in shaping the economic performance of this sector. Decisions on exploration and development, on the nature and level of manufacturing activity carried on with feedstock inputs, and the location of various other activities in Canada or elsewhere in the international structure of the enterprise are necessarily influenced by these features of the industry. The concentrated nature of this industry both in Canada and internation-

[1] This is based on a sample of firms having assets of $5 million or over. The average size of all Canadian controlled firms would be smaller.

ally, and the various other factors which influence international investment and allocation decisions by criteria other than real underlying efficiencies (such factors as tariffs, tax policies of various jurisdictions, policies of various countries with regard to location decisions and pricing practices and, to a lesser extent, foreign exchange controls and foreign investment policies of various countries) affect the structure and activities of international firms operating in Canada.

These influences also mean that the Canadian unit within the international corporate structure of a particular firm is not free to optimize its results by whatever measure of performance one might choose—profitability, sales level, etc. For example, in sourcing its crude, the Canadian subsidiary of a multinational firm would be expected to give some preference to the crude owned by its parent or affiliates elsewhere in the world. Indeed, it would be disadvantageous to the overall profitability of the multinational enterprise for a Canadian subsidiary to buy its inputs from a source other than an affiliated company if in doing so it were to pay a price which is lower than the one which it would be required to pay to the affiliated firm, but above the price at which the affiliate could sell to some other purchaser internationally. The Canadian subsidiary contributes to the overall profitability of the international operation so long as it contributes to the overhead of the global operation, even though the transaction might be sub-optimal from the viewpoint exclusively of the Canadian business operation.

The Balance of Payments

Business operations in the energy sector, like any industry involving international transactions, affect the international movement of funds and hence the balance of payments of the country.

Balance of payments is an aggregate phenomenon through which any movement of funds internationally requires some compensating adjustment. This adjustment may take place virtually anywhere in the economy—either through transactions in the sector of the initial movement or through adjustments in other industries. In both cases this adjustment can occur through either capital movements or trade and service activities. From a balance of payments point of view the fundamental effects of any given project are found in the resulting net change in capital inflows which by one adjustment process or another will be matched by an offsetting movement in the current account.

Foreign investment involves an initial capital inflow to the extent that the funds involved are drawn from outside Canada. Foreign investment, regardless of the source of the actual financing, also involves continuing payments abroad in the form of dividends. Interest paid on foreign-sourced loans and other business service payments of a non-merchandise nature (such as management fees, engineering fees, royalties, etc.) are other forms of payments made abroad some of which are linked to foreign direct investment. (The export of the commodities produced involves significant financial inflows in the energy sector and the purchase of goods and services can involve some outflows but these may be little affected by foreign investment in this sector.) The foreign control of energy projects, to the extent that it involves more and different international trans-

actions and remittances than a Canadian-controlled project, can have a balance of payments impact over the life of a project which differs from a comparable Canadian-controlled venture.

A full exploration of the balance of payments aspects of the energy sector would require not only an examination of the magnitude of these flows but also a tracing of their repercussions on the rest of the economy in terms of the effect upon the allocation of real resources and financial movements. To assess the significance of foreign control in this respect would require an identification of the different impacts of foreign and Canadian controlled projects, and their tracing over the life of the project. While this cannot be undertaken here, the magnitude of the movements involved in energy might be illustrated by data drawn from the petroleum industry. A few general tendencies which would appear to be associated with foreign control in this industry can be indicated. While the few differences which could be identified would not suggest that any adjustments posed for balance of payments by foreign direct investment hinge on the nationality of the owners, the size of the payments involved by direct foreign investment is significant. Futhermore, many developments in this industry have, in fact, relied heavily on foreign direct investment so that the general balance of payments trends of this industry and their timing would undoubtedly have been different in its absence.

The fact of a difference cannot be taken to imply any assessment of whether that difference is undesirable. From a balance of payments point of view it can only be said that an adjustment is necessary elsewhere in the payments structure. Of greater ultimate importance from the perspective of foreign investment and industrial development is the impact of these activities on the allocation of real resources in the Canadian economy. While the allocation of resources can be affected by the magnitudes and mix of international payments due to the adjustment to which they give rise, there are many other market factors which also affect this resource adjustment.

It will also be seen that the petroleum industry has, in recent years, experienced a significant shift in its international payments effects as the existence of a Canadian industry has displaced some imports and developed substantial export sales. The statistics on international transactions of the oil and gas industry represent only the rough magnitudes and trends due to the estimation techniques employed. In the period 1965-1968 the payments related to the oil and gas industry were in approximate balance with capital inflows offsetting the deficit on the current account. While the trade account turned around from a small deficit, the service account had substantial and reasonably constant net outflows due mainly to payments abroad of dividends and interest. The resulting deficits on the current account although declining, remained large and were on average offset by the inflows on the capital account. After 1968 the balance of payments for this industry began to show substantial surpluses. In 1969 and 1970 the surplus amounted to about $350 million. Most of the improvement in the sectoral balance of payments in these two years was accounted for by a sharply rising trade surplus resulting mainly from growth in the export of crude petroleum.

In terms of Canada's overall balance of payments, the oil and gas industry is an important factor. In 1970 oil and gas exports amounted to almost 6% of

total exports, while imports by this sector accounted for 4% of total imports. These relative proportions had reversed from their 1965 levels, thereby reflecting the contribution of this sector to Canada's increasing trade surpluses. In 1970 the trade surplus of the oil and gas industry accounted for over 10% of the overall

TABLE 2

SUMMARY OF SECTORAL BALANCE OF PAYMENTS FOR THE OIL AND GAS INDUSTRY[1]
($ millions)

	1965	1966	1967	1968	1969	1970
Current Account	**−249**	**−205**	**−183**	−165	−92	83
Trade Balance (3+6)	**−92**	**−70**	2	**10**	**128**	**304**
1. Commodity Exports	404	466	570	652	775	950
Crude Oil & Equiv	(280)	(330)	(402)	(452)	(538)	(658)
Petroleum Products	(22)	(26)	(36)	(46)	(57)	(82)
Natural Gas	(104)	(110)	(133)	(154)	(178)	(210)
2. Commodity Imports	482	510	552	616	620	608
Crude Oil & Equiv	(312)	(326)	(342)	(374)	(394)	(414)
Petroleum Products	(160)	(164)	(176)	(206)	(210)	(188)
Natural Gas	(8)	(20)	(32)	(39)	(18)	(5)
3. Trade Balance on Commodities (1-2)	(76)	(42)	20	36	154	342
4. Merchandise Exports[2]	20	18	20	22	36	40
5. Merchandise Imports[2]	38	46	40	48	62	77
6. Trade Balance on Merchandise (4-5)	−16	−28	−18	−26	−26	−37
Net Services	−157	−135	−185	−175	−221	−222
Dividends, Interest	−130	−114	−145	−132	−182	−149
Payments	−152	−129	−159	−171	−218	−196
Receipts	22	15	14	39	36	47
Other services (net)	−27	−21	−40	−43	−39	−73
Payments	−32	−26	−50	−52	−52	−79
Receipts	5	5	10	9	13	6
Capital Accounts	**211**	**302**	**193**	**245**	**443**	**261**
Net Capital Movements into Canada:						
Direct Investment (net)	104	176	114	143	146	230
Portfolio Transactions (net)	98	73	21	152	321	73
Other Long-Term Loans (net)	39	−5	28	28	19	8
Net Capital Movements Abroad:						
Direct Investment (net)	−8	124	−16	−45	−62	−33
Portfolio Transactions in Foreign Security (net)	nil	nil	nil	nil	nil	−2
Short-Term Transactions (net)	−22	−66	46	−33	19	−15
Sectoral Surplus or Deficit (−)	−38	97	10	80	351	344

SOURCE: Statistics Canada. Totals may not add due to rounding.

[1]The data used here under the Oil and Natural Gas Industry includes shipping and pipeline companies and gas distribution companies along with exploration and development, refining and merchandising companies included in previously quoted statistics.

[2]The data represents an aggregation of specific trade accounts [52179, 52199, 70994 (imports) 89099 (exports) 52117 (imports), 52119 (exports)] which were assessed to represent the main categories of trade in oil and gas related equipment and supplies. The data does, however, due to exclusions and unrelated inclusions, only represent a rough approximation to merchandise trade by this sector.

Canadian trade surplus. Regarding services, the oil and gas industry deficit reflected the general trends in the Canadian economy and contributed almost 12% of the net outflow on this account. However, in terms of importance, the impact on Canada's capital account is perhaps the largest. Of total direct investments in Canada in 1970, the oil and gas industry accounted for almost 30%, while only accounting for 12% of the outflow due to direct investment overseas. Taking all the transactions for the oil and gas industry on the capital account, the industry contributed over 55% of the balance in 1970. Although high during this year and volatile during recent years, this proportion averaged 34% in the years 1965-1969, with a low of 16% in 1965 and a high of 54% in 1968.

Since the great bulk of the investment in this sector is under foreign control, the relatively comparable portion of the total movements shown in the earlier table would be accounted for by the foreign controlled sector. For example, the great bulk of the net capital inflows in the sector and the outflow of dividends and interest would be accounted for by the foreign controlled firms. In marked contrast, however, almost all of the investment abroad by Canadian corporations in this industry are undertaken by the Canadian controlled firms. Over the period 1965-1970, the Canadian controlled firms made net new investments abroad of approximately $107 millions. The foreign firms in Canada which are under U.S. control actually repatriated $114 millions of investments they had made abroad although this is an unusual event, explained by the sale of a major foreign asset by a U.S. controlled firm in Canada. Other foreign controlled firms made investments of $47 millions abroad in that same period of time.

In the case of service payments made abroad (excluding dividends and interest payments), the foreign controlled sector again accounts for the greatest bulk of this outflow. Approximately 90% of the payments made abroad for services in this sector are made by the foreign controlled firms—with no breakdown available as to the services purchased from affiliates and those purchased from unaffiliated companies. These firms account for a smaller percentage than 90% of the total assets in the industry when account is taken of the inclusion in these statistics of shipping and pipeline companies as well as gas distribution companies along with the exploration, development, refining and merchandising companies.* This data would suggest that the foreign controlled firms have a greater propensity to purchase services abroad than their Canadian controlled counterparts.

It can be seen from Table 2 that Canada imports petroleum products at an annual value of approximately $200 millions. This is approximately 50% of the value of crude oil imports. On the export side, however, Canada exports considerably less—ranging from $22 millions to $82 millions over the period of 1965 to 1970—representing on average about 10% of the crude oil exports. Since virtually all of the processing of crude into various petroleum products is done by foreign controlled companies in Canada, there is no basis of comparison but it is clear that processed exports are quite low. The reasons for this have been suggested earlier to include some impact from foreign tariffs which restrict exports and also restrict the potential for the realization of economies of scale in Canada on the basis of the smaller market opportunities—and probably also some in-

* The 91% of assets which was noted earlier as controlled by foreign interests excluded the shipping, pipeline and gas distribution companies.

fluence from the fact of foreign control of these processing facilities in Canada by the same firms which control similar facilities in the United States from which the needs of that market would tend to be served.

The expenditure of some of the invested capital and earnings on Canadian goods and services generates incomes in Canada which can lead indirectly to higher imports of goods and services to satisfy the consumer demand which that income generates. An inflow of capital can affect interest rates or price levels which in turn induce compensating adjustments in other transactions over the border. Measures of these indirect effects are not, however, available.

The complete assessment of the effect on balance of payments of a project would involve, as well, the difficult consideration of what would have occurred in the absence of a particular project. We have seen earlier that the petroleum industry now generates a net surplus on the balance of payments on a current year basis. The petroleum industry and the energy sector generally would likely have a net surplus-creating direct impact on Canadian international transactions even over the life cycle of a project when one considers the magnitude of the investment capital inflows, the sale of commodities when the energy resources are exported, and the expenditures in Canada on equipment, plant, labour and services. Data is not available, however, to assess this on a life of project basis. Furthermore, the importation of energy products would likely have been higher in the absence of these investments so that the outflows involved in those transactions have probably been reduced as Canada has reached a net export position in, for example, oil and gas trade. The maturity of a project could, of course, affect this impact. If earnings are not re-invested in Canada, the drawing-off of profits and disinvestment can involve significant outflows. While the balance of payments effects of energy projects merit considerable attention, the balance of payments adjustments would not appear to have turned frequently on the issue of foreign control.

Conclusions

An attempt to sum up the impact of foreign direct investment brings out the fact that the effects can be felt in a variety of aspects of industrial structure and performance. It would be artificial and misleading to allege any "net" impact since the variables do not lend themselves to any single measure. Furthermore, in considering individual instances of foreign control, a range of observed performance and effect is probable, depending upon the actions of the firm involved and upon the surrounding circumstances.

Foreign direct investment can add to the level of economic activity and employment—especially in certain regions of the country where energy resources form an important part of the economic and industrial potential—if the project would be unlikely to proceed without the foreign investment, or if the project would be delayed without that investment. What events might have occurred in the absence of a particular project and what government policies might have emerged is, of course, difficult to determine.

The foreign investment might advance the productivity of an operation if it introduces superior technology or more efficient management. It might provide an entrepreneurial initiative that might not otherwise have been taken. Large capital

pools necessary for individual projects have often been difficult to gather in Canada. At times, assured export and perhaps domestic markets which are essential to such large scale investments may have come along with the foreign investment.

These investments have historically contributed to growth, employment, incomes and government revenues in Canada. The reduction of imports and the development of exports have contributed to a strengthening of Canadian balance of payments.

Foreign controlled operations might, however, have been able to contribute more to Canadian economic activity if they were to have procured more goods and services locally, undertaken more research and product development in Canada, and expanded the downstream processing and manufacturing of some of the energy resources—where this is economically reasonable. The international allocative process—influenced as it is by the policies of various governments (restrictions on trade and investment decisions, tax policies and other inducements, and interventions which affect capital movements) and by the international industrial structure which is quite concentrated in such industries as petroleum, may not be according Canada the level and balance of economic activity of which it is capable and to which it aspires.

For the future, it is necessary to consider whether foreign investment which controls a Canadian enterprise remains necessary to the realization of Canadian objectives in this sector. The improvement of Canadian capacities in the undertaking of these projects and the evolving market conditions for energy products may make foreign control less necessary. The rate at which Canadian capacities now permit development might be perfectly compatible with our goals.

Similarly, it is relevant to consider whether the performance of this sector might be enhanced by a variety of public policies. The achievement of Canadian control may not affect the performance measurably. The preceding analysis suggests that the areas of concern can be attributed to foreign control in part only. (There is very little data available for a comparison of the Canadian and foreign-controlled firms in many of these industries and the factors which influence the foreign firm might not be too different in the case of a Canadian counterpart.) Furthermore, the best techniques for dealing with these concerns, even if contributed to by foreign control, may not be to eliminate that control if this would involve the foregoing of advantages inherent in the foreign direct investment or the undertaking of developments which are considered desirable. A simplistic solution could have a seriously adverse effect on living standards in Canada.

Foreign control is of significance, as well, from the perspective of the "economic rent" which is often present in resource development. Many energy resource developments involve an economic value which exceeds the cost of extraction, preparation for use, and a return to the capital employed which would be sufficient to attract the investment. This value, reflected in the price charged to users, when compared with these total costs helps to allocate the use of the commodity and provides the incentives for the exploration for further resources. The economic rent is captured in part by Canadian governments through taxes, royalties and similar payments, and partly by the Canadian public through incomes and perhaps prices (if they reflect the greater availability of the resource once discovered). The re-

maining gain accrues largely to the foreign owner through the profits received ultimately from the investments and through other transfers of funds.

This analysis has focused thus far on the economic and industrial aspects of foreign direct investment. There are other concerns relating to the impact of high levels of foreign control on Canada's ability to determine its own priorities, to shape its environment, and to provide opportunities for Canadians to do the kinds of things they find satisfying. A high level of foreign control, particularly of industries of widespread importance, does reduce this kind of domestic control. Foreign control of Canadian businesses and the international perspectives of such firms as the large and integrated enterprises in the petroleum industry does increase Canada's exposure to external influences or decisions which affect Canadian activities and priorities. This is probably further complicated by the dominance of a single country, the United States, as the location of control of the foreign investment in Canada.

A variety of policy devices should be looked to in dealing with these concerns. No single policy can be expected to remove the concerns expressed in this section for maximum benefits in a variety of areas, minimum restraints on Canadian opportunities and the greatest degree of domestic control. These policies must be compatible with the fact and desirability of Canadian international involvement and the aspirations of Canadians for high living standards. Furthermore, the varied regional circumstances and the interests and responsibilities of all provincial governments must be taken into account in considering federal policy initiatives in this area.

Chapter 3

THE EXISTING FOREIGN CONTROL POLICIES

Many provincial and federal laws and regulations are now in effect that influence the activities of foreign controlled energy companies in Canada. A bill currently before Parliament would seek to ensure that proposed takeovers of Canadian companies and new foreign businesses wanting to establish in Canada will bring "significant benefit" to Canada.

The petroleum industry is under provincial regulations where applicable, but also comes under supervision of three federal government departments or agencies.

The export of oil, gas, uranium and electricity; control of interprovincial pipelines; activities in the Arctic and offshore are controlled by the federal government. The right to hold leases in federal lands is subject to some limited requirements regarding an opportunity for Canadian participation. Restrictions on the foreign ownership of uranium were announced in 1970 adding to the existing regulations by the Atomic Energy Control Board.

New tax regulations which have been recently introduced would tend to support further processing in Canada. Government participation through Panarctic Oils Ltd. and Eldorado Nuclear Ltd. also ensure Canadian participation in some energy activities.

Canada presently has a wide list of laws and regulations, at both provincial and federal levels of government, which influence the role of foreign-owned and controlled companies active in the energy industries. Here is an outline of how activities of these organizations are being regulated and directed.

The Foreign Investment Review Act

This Act was introduced into Parliament in January 1973 and will have application to energy industries. This legislation would establish an agency to review foreign acquisitions of Canadian businesses (whether owned formerly by Canadians or non-residents) and, upon separate proclamation (which is intended to be later than the takeover portion), the establishment of new businesses in Canada by foreign interests. Proposed takeovers and proposed new investments in lines of business unrelated to existing operations of a foreign controlled firm would be reviewed to determine whether they would bring "significant benefit" to Canada. Cabinet would then allow or disallow such investments depending upon their findings. The investor would be consulted as to revisions of his plans and possible additional undertakings which would make the investment of significant benefit to Canada.

This legislation would not apply to a foreign firm presently doing business in Canada that is not acquiring another business or establishing a new business in any field related to its existing line of business. Much foreign activity in the energy sector would therefore be unaffected by this legislation.

Federal Legislation of Performance in Petroleum

Aside from ownership and processing rules, the federal government does regulate several aspects of the petroleum industry.

Behaviour is controlled by both federal and provincial regulatory bodies and other government departments. In the federal domain three agencies directly control oil and gas industry activity in Canada:

The National Energy Board

The Resource Management and Conservation Branch of the Department of

Energy, Mines and Resources

The Northern Natural Resources and Environment Branch of the Department of Indian and Northern Affairs.

National Energy Board: Under the National Energy Board Act, the Board's functions are two-fold, regulatory and advisory. The Board acts as a regulatory body in the issuing (with the approval of the Governor in Council) of certificates of public convenience and necessity for the construction of interprovincial and international pipelines, as well as the issuing of licences for the import and export of natural gas and natural gas liquids. This jurisdiction also includes the export of electricity and, most recently, now includes oil exports. In evaluating applications, the Board considers such factors as the adequacy of reserves to meet Canadian needs, and the prices in the delivery market and the price at which the proposed export is contracted. (Provincial authorities regulate local distribution, pipeline systems, marketing and pricing of gas in Canada.) In addition, the Board is charged with the implementation of adequate standards of construction and operation in order to ensure the safety of any facility which it has certified. The Board also has the authority to regulate the tolls charged by oil and gas pipeline companies under its jurisdiction to ensure that such tolls are just and reasonable. Lately the Board has required environmental impact studies in certain cases to determine the environmental consequence of actions under consideration.

Resource Management and Conservation Branch (EMR) and the Northern Natural Resources and Environment Branch (INA): Essentially these two agencies' functions are quite similar—differing only in the geographical areas administered. The Resource Management Branch administers and manages all aspects of the federal interest in petroleum and natural gas resources offshore from Canada's west and east seacoasts and in the Hudson Bay-Hudson Strait region, as well as those federally-owned mineral rights in the provinces that become available for disposition. The duties of the Northern Natural Resources and Environment Branch are similar, but apply to federal lands north of the 60th parallel including the Arctic Islands. Specifically, it is the intention of both departments to provide a regulatory climate that will best encourage and provide for active exploration and orderly exploitation of the oil and gas resources on federal lands. Their regulations influence industry behaviour in many ways but most importantly through time limits and work requirements. Under these regulations the land must be explored and developed within specified time limits or it reverts back to the Crown.

Other Resource Control Mechanisms

The recent revisions to the Canadian Income Tax Act introduced new measures with respect to the processing of mineral ores up to the prime metal state. These new measures will allow a depletion allowance of 33⅓ per cent of the processing profits in cases where the ores processed are not from a mine owned by the taxpayer. In addition, machinery and equipment purchased for the processing of the mineral ores will be eligible to 'earn depletion'. The earned depletion deduction will replace the present automatic depletion in 1977.

There are very few provisions in the acts and regulations on mineral exploitation that relate to foreign ownership. The only restriction on the exploitation of minerals under federal jurisdiction is included in regulations providing for the disposal of oil and gas rights in the Yukon and Northwest Territories and offshore areas. Similar provisions are included in the regulations providing for the disposition of mineral rights in the Northwest Territories and offshore areas. Under these rules a lease may not be granted to an individual unless he is a Canadian citizen; or to a corporation incorporated outside Canada, or to any corporation unless at least 50% of its shares are owned by Canadians, or unless the shares are listed on a Canadian stock exchange. These requirements do not take effect before the production stage, that is, there are no restrictions at the exploration phase. As for the lands under provincial jurisdiction, there exists no restrictive legislation on foreign participation or ownership in mineral development.

The Canadian government announced some restrictions relative to foreign ownership of uranium on March 2, 1970. The announcement stressed that new regulations would attempt to accomplish two main objectives: the implementation of the government's new policy on foreign ownership of uranium, and the equitable treatment of those companies operating or exploring in Canada under the previous rules of the game. Companies not presently engaged in mining operations will have six years to demonstrate that they have an economically viable uranium ore deposit before they become subject to the new rules imposing a maximum total foreign ownership of 33% and a maximum individual foreign ownership of 10%.

The Atomic Energy Control Act gives wide powers to the Atomic Energy Control Board over the exploitation of uranium and thorium and over export activity. Export contracts are reviewed to assure accordance with Canadian policy regarding the peaceful use of uranium and that the contracts in their economic aspects are in the national interest. Such aspects include the relationship between contracting parties, reserves, rate of exploitation, domestic requirements, domestic processing facilities, and selling and pricing policy. In the latter regard, approval will not normally be given to contracts of more than 10 years' duration unless provision is made for renegotiation of price.

There are cases where governments in Canada have assumed a very direct role. One recent example is the federal government's 45% participation in Panarctic Oils Limited along with a number of private sector corporations. Panarctic has under lease extensive areas of land favourable for oil and natural gas on Canada's Arctic Islands and is pursuing an intensive exploration program. The government is also involved directly in uranium mining and processing through the Crown Corporation Eldorado Nuclear Limited.

The Canada Development Corporation was established by a special Act of Parliament in 1971 as a corporation 'that will help develop and maintain strong Canadian-controlled and managed corporations in the private sector of the economy and . . . give Canadians greater opportunity to invest and participate in the economic development of Canada'. While the government is currently the sole shareholder in the CDC, the corporation is expected to begin offering shares to the public in the near future. The CDC has identified six areas in which it plans to concentrate its initial investment effort. Among them are: the petroleum and natural gas industry; mining, smelting and refining; and pipelines and related northern transportation. The CDC is a participant in Canadian Arctic Gas Study Ltd. and has expressed an interest in purchasing the government's share-holdings in Panarctic. The CDC has also publicly indicated a willingness to purchase one-quarter of the equity of a Mackenzie Valley gas pipeline, on the assumption that the equity of this project would total $1 billion.

In addition, the government also regulates industry operational activities. In this regard, the federal government has announced a set of seven preliminary guidelines governing the construction and operations of northern oil and gas pipelines.

Chapter 4

FUTURE OPTIONS

The energy industries are influenced by the general array of federal and provincial legislation and will be affected by steps taken generally to influence the activities of foreign controlled firms. How much further action is desirable on this subject in the energy sector depends upon observations as to the impact of the foreign ownership and control as well as upon Canadian goals. Any additional policies would have as their purpose the optimizing of benefits to Canadians from energy industry development.

This objective would best be advanced by a mix of policies. Policies dealing with energy issues generally, regardless of the nationality of the investor, will deal with some aspects. Additional initiatives could include efforts to increase Canadian capacities to undertake energy development.

The analysis in this section has attempted to describe the degree of foreign control of energy resource industries and to assess the impact it has upon the realization by Canada of the potential benefits from its activities. Foreign investment is neither the sole, nor perhaps the most significant cause of the industrial structure and performance which exists. Foreign investment does, however, in any individual instance, involve a variety of potential costs and benefits—some of which cannot be readily quantified by virtue of incomplete data, the absence of Canadian comparisons, or the somewhat unquantifiable nature of some of the concerns which underlie public sentiment on foreign control.

General Energy Policy

In identifying potential benefits to Canada from energy development, and framing policies for their implementation within the present context, an energy policy would itself deal with some of the issues discussed in this section of the document.

A revised federal policy on the collection of economic rents, for example, could redistribute some of the economic benefits. To the extent that a greater proportion of the economic value is captured by such a system, any concern over the loss of an excessive degree of the economic value of energy development to a foreign jurisdiction by virtue of foreign control would be reduced. A reasonably flexible set of financial terms would aim at securing an acceptable proportion of the economic value for the Canadian economy while continuing to support the level of development considered desirable.

The degree of foreign ownership and international links of the firms might influence such policies, but the policies are important on their own merits and quite independently of a foreign investment policy. The same would likely be true of other areas of concern regarding the performance of foreign controlled firms. A sound energy policy can reduce some of the disadvantages otherwise associated with foreign investment.

Similarly, some of the "gaps" suggested earlier as contributing factors in the level and nature of foreign investment might be dealt with through general economic or industrial policies. For example, policies to improve the performance and capacities of Canadian capital markets would facilitate Canadian control of energy projects, perhaps reduce the number of foreign takeovers, and reduce the likelihood that foreign control of new projects will result from an inability to put the capital and entrepreneurship together from Canadian sources. The development of efficient manufacturing capacities and the revision of international trade restraints would also affect the energy sector and its downstream activities. Some specific policies might be appropriate for certain concerns. For example, the concern for appropriate levels and kinds of R&D activities in Canada might be dealt with directly.

Additional Policy Initiatives

Changes in general industrial and energy policies are not able to get at some of the factors which affect international investment and the way it operates in Canada. Some of these matters are rooted in institutions and policies outside of Canada. Furthermore, Canadian participation and the optimization of the benefits of foreign investment cannot alone dictate the terms of general policies which have a variety of objectives. The realization of our objectives in the area of domestic control might best be achieved by policies aimed directly at these issues. Also, some general approaches may not permit the realization of the benefits of foreign investment while reducing its disadvantages or eliminating its unnecessary or undesirable instances. Lastly, considerations which are not solely of an economic nature may justify a concern for Canadian ownership or domestic control.

In this regard, a variety of policy approaches have been suggested in public discussions and should be assessed; each has a variety of advantages and disadvantages in the context of the energy sector.

Canadian participation in the equity of all firms in the sector—e.g. 51% Canadian ownership of the equity in all energy companies, or perhaps in all new ventures;

Joint ventures involving Canadian partners—private or public;

Carried interest rights for a public authority leading to "participation" in the firms involved;

Public ownership of a firm in this set of industries;

More extensive use of a review procedure in the investment made in the energy sector.

This list is not intended to be exhaustive. The techniques for implementing these methods and a full assessment of the likely effects is, of course, essential to any discussion of such policies. The material provided in this report and Appendix B should assist.

SECTION VI

ENERGY IN OUR HUMAN AND NATURAL ENVIRONMENTS

Chapter 1

CANADIAN ATTITUDES TOWARDS ENERGY

Canadian attitudes towards energy are uniquely our own. They are based on our energy needs due to our rigorous climate and an assumption that we can have the joys of both city and country living. How our attitudes developed has its origin in the earliest history of Canada and in an unusual mixture of circumstances and views. The result is that one major characteristic of the Canadian life style is a very high consumption of energy.

The early use of energy by Canada's native peoples, the Indians and Eskimos, was part of a balanced system of life. On this has been superimposed a high-energy technology which is not balanced but expanding and open-ended. Much of the undeveloped potential for energy resources in Canada lies in areas where Indian and Eskimo life patterns will be affected. Energy policy will have to take into account the attitudes and goals of all Canadians.

The history of the development of Canada has led to the assumption that we are both a developing and a developed country, and that as a people we are, or ought to be, both close to the land and, no matter where we live, full partakers of the amenities of sophisticated modern city living. The attempt to live up to this assumption has had a lot to do with the modern Canadian way of life and our use of energy.

What we have done, in creating Canada, is to take European-type forms of business administration and social habits, plus American technology and products, arrange them according to a pre-existing native trading and transport system, and apply them to build communities which have an urban life style regardless of their size, location or climate, at widely dispersed places across undeveloped land. To make this unlikely mixture work we have applied energy liberally. The result is a Canadian way of life which has similarities to many other life styles but is unlike any other. It is characterized by a very high consumption of energy per capita just to keep it operating.

It has been observed about energy consumption that Americans enjoy it, while Canadians need it. Part of the Canadian need for energy is due to our more rigorous climate and more thinly dispersed population. Part is the consequence of our successful efforts in living up to our assumption that we can have, in both city and country and in all parts of the nation simultaneously, the advantages of city and country living. The following three examples may show how this assumption affects the structure of our society and the consumption of energy;

Whereas most societies that live in cold regions have developed small living quarters to save heat, Canadians almost from the beginning have provided themselves with indoor living areas at least as large as and commonly larger than those of warmer countries. This has been done on the grounds that fuel and land space are available and if people are going to spend so much

time indoors they might as well enjoy it. A large house or barn is also a psychological defence against nature just outside the door. We have carried the same philosophy over to our schools, factories, and public buildings, where our norms for cubic space per occupant are among the world's highest. As a result, we have used energy liberally to give us an indoor freedom that no other nation possesses.

Our pioneer mythology, our background of immigration from countries where land was scarce, and the relative availability of land in Canada have all led to a Canadian norm of land space round a dwelling (front yard, back yard, boulevard) whose prime purpose is to separate the dwelling from others. The pursuit of this norm has led to suburbia, ribbon development, dormitory towns, etc., which bring attendant problems but which also give the majority of Canadians a quietness, privacy, and spaciousness yet convenience of living that are enjoyed by few other people. As a result, a small Canadian city occupies almost ten times the surface area of a typical European city with the same number of inhabitants. Thus although Canada is among the most highly urbanized countries in the world (in 1971 76.1 per cent of the total population was classed as "urban" and two out of every five Canadians lived in a city with a population greater than 100,000) in no other country have people in ostensibly urban regions spread themselves so widely over the land. All of this is possible only by the application of abundant energy for personal transport, goods distribution, individual dwelling heating units, etc. This in turn creates a feedback that leads to consumption of more energy:—two-car families, power lawnmowers, home workshops, etc. Even though there is a recent trend in some parts of Canada toward greater use of multiple-family housing structures, particularly high-rise apartment units, many of these are being built in parks and suburbs, and the life style they offer is not conservative of energy.

Canadians use energy to gratify the desire to be both a city and a country people. We have a national passion for a second place to live, occupied part time only, just for pleasure, and usually in the country at some distance from our regular dwelling. Many of us attach great importance to being able to spend our holidays at a summer cottage, tourist camp, or ski lodge, and many devote a considerable amount of disposable income to it. The maintenance of such places, the activities pursued there, and the going and coming, are all likely to require considerable amounts of energy. To a large degree our enjoyment of life is dependent on our having ample energy to use or not to use as we see fit.

These various peculiarities of Canadian life are ones which should be acknowledged and considered when deciding on the directions which future energy policies should take.

Energy and the Place of Native People in Canadian Society

The Indian and Eskimo people of Canada feel, with justification, that they have been pushed aside and prevented from useful participation in the prosperity and

development of the Canadian society to which they gave such a successful start. More than most other Canadians they are aware of the intimate connection between energy and modern life. The problems connected with attitudes of society run more deeply, but much of the cultural and social stress in which Indians and Eskimos are involved today manifests itself through the change of life style consequent upon the introduction of a high-energy technology, with its open-ended view of consumption, production, and pace of life, into a previously balanced life system.

Like other Canadians, most native Indians and Eskimos participate fully in the assumption of unlimited energy supply and the right to use it. Most also believe that the Canada to be desired is one which combines a closeness to the land and nature, with modern material comforts and advanced technology. But these assumptions have quite different connotations if one is an Indian or Eskimo, and the role that energy plays is seen in a different light.

The cultural traditions of Indians in all parts of Canada, and of Eskimos, arise from a way of life in which man was a consciously involved part of the local natural ecosystem. The system was not conservation-oriented, but the interaction between individual activities and other components of the ecosystem was so direct and immediate that a balance was maintained between human prosperity and the immediate biological productivity of the region. In this system, energy, other than muscle energy, played a minor role. Its use and control were reasonably well understood—anyone who heats a snow house with a soapstone blubber lamp without the benefit of matches is quite sophisticated in energy engineering—and it was neither in short supply nor expensive. Yet the use of increasing amounts of energy was not important to increased success and prosperity. In this tradition, where one's identity comes largely from attachment to the land, and one's self-esteem and the respect of society comes not from material advancement but from ability to make use of immediate resources and wisdom in community and family affairs, the ability to use energy is important, but the use of energy itself plays a minor part.

Into this society has come a technology based largely on equipment made with the help of centralized industrial energy and used through the rapid release of stored energy. The "new" way of life is seen by both native peoples and by those who are introducing it as characterized by material goods and faster, longer-range techniques: guns, outboard motors, aeroplanes, oil stoves, snowmobiles, radios—all of which are dependent on, or use, energy or power foreign to the traditional Indian and Eskimo life. The energy put into a rifle bullet when it is fired may not be greatly different from that put into an arrow when it is shot from a bow; but the difference between energy that was expended on the rifle and bullet before it was fired and that which went into making the arrow and drawing the bow has made the bullet more effective. In many cases, this difference ultimately has altered the ecosystem in which the native people belonged, both by harvesting game faster than can be replenished naturally, and by making the people dependent on and part of, a larger and more integrated economic system. Such a change, induced by the availability and use of energy, brings with it all the problems of cultural shock, economic disorientations, and social conflict that are being experienced by Indians and Eskimos today. Our national energy policies cannot help having an influence on these problems, and it is a national responsibility to ensure that the influence is constructive.

Some of the importance given to the relation between energy policies and the place of native peoples in our society arises from the fact that the potential energy resources of the hinterland of Canada offer at the same time a real hope and opportunity for wealth and income to benefit native people in many parts of Canada, and a serious threat to their social stability and hold on the land which is the chief base for cultural identity. Problems connected with oil development in the Mackenzie delta or on Banks Island, or hydroelectric development near James Bay, are current issues in Canada, and they are likely to be followed by others. Such problems are in themselves restricted, but they strike deeply into Canadian attitudes and goals. They may be defined on economic grounds, but they cannot be solved by economics alone, and we are ill-equipped both legally or through expression of public attitude to solve them otherwise. The solutions we come to will be in considerable degree an expression of our energy policies and its relation to Canadian society.

Chapter 2

ENERGY AND THE NATURAL ENVIRONMENT

The use of energy is fundamental to Canadian well-being and prosperity. At the same time, activities connected with the production and use of energy, and disposal of waste products from energy use can, if not controlled, degrade the quality of the air and water, and make land unfit or unattractive for other uses. Energy activities have contributed importantly to a deterioration of the quality of the environment in many parts of Canada and Canadian energy activities contribute to undesired changes in the world environment. Canadians are aware of the threat to the environment of increased energy production and use without environmental control, and have initiated programs on both federal and provincial levels to preserve environmental quality.

It is possible with presently known technology to restore the natural environment in Canada where it has been damaged, and to maintain that quality at an acceptable level of quality in all respects during the production and use of the forms of energy used today. The most important requirements are assessments, prior to development of energy activities, of the immediate and long-term impacts on the environment, and design and selection of techniques and processes that will avoid, rather than repair, undesired environmental changes. Research and further technical development are required to improve the economy of environmental protection and the efficiency of resource use, and to ensure that there will be no adverse environmental consequences from subtle or cumulative effects of energy use, or from new forms or methods of making and using energy. However, there is no doubt that if Canadians really want to do so, they will be able to enjoy both ample energy for all anticipated needs in the future and a high quality, healthy and attractive environment. The cost of environmental protection while producing energy to meet future needs will be substantial, but not great enough to have an important effect on the overall cost of energy or its pattern of use.

What will be needed to ensure environmental quality during future energy growth are an awareness on the part of Canadians of the environmental effects of their present energy-using habits, a determination to undertake thorough environmental assessments and to act on the findings, a willingness to weigh the long-term environmental consequences and costs of major energy developments in relation to the benefits before decisions to develop are undertaken, and the courage and ability to decide on priorities of land use.

Canadians are becoming increasingly aware of present trends leading to the deterioration of the quality of our environment, and they are indicating clearly that these trends must be halted and reversed. Despite our variety of backgrounds and local situations, as a nation we have a fairly uniform opinion of the kind of country we want as regards the quality and cleanliness of its air and water, and the healthfulness of the natural surroundings.

The activities associated with producing and using energy, and the waste products of energy conversion can, if improperly handled or controlled have serious and undesired effects on the quality of the atmosphere, waters and soils. Dangers exist to the health of our vegetation, wildlife and stock, and indeed to ourselves. Many of our activities connected with energy disturb the terrain and make the land unfit for other uses.

The effect of ignoring or paying little attention to environmental considerations could be an impairment of the present and long-term productivity of the country, and a decrease in its perceived and real value for subsequent human use and enjoyment. In some areas this impairment has already happened. Therefore, Canada's national energy policies must always consider the impact of energy production and use on the national environment if we wish to achieve these two main goals:

To provide adequate energy for the country's needs, now and in the future, in the most efficient and economical manner while at the same time ensuring that on both a local and regional basis the long-term quality of the natural environment, in tangible and also intangible terms, is maintained at an acceptable level;

To enable Canada to fulfill her obligation, made at the United National Conference on the Human Environment, to contribute to the solution of global environmental problems arising from the use of energy, and in demonstrating how national needs for energy can be met without adding to the environmental problems of other nations or future generations.

A review of the environmental issues in Canada with respect to energy activities anticipated in the next three decades (*see* Appx. A, Part 2), leads to the following conclusions:

Environmental quality must be achieved and maintained by avoiding or directly controlling the environmental impact of energy activities.

Technology is available at present to achieve and maintain national objectives of environmental quality while still providing adequate energy for Canadian needs in the next three decades. Anticipated improvements in technology, and environmental awareness by operators and the public, should progressively improve the effectiveness and economy of maintaining environmental quality.

The cost of maintaining satisfactory environmental quality, while considerable, will not likely disrupt the economy or fundamentally change the pattern of energy use.

It is feasible for costs of maintaining environmental quality to be met by direct increases in the cost of energy and energy-consuming products.

To achieve maximum economy and efficiency in the use of resources with full protection of the environment, it will be necessary to employ, within the basic national environmental objectives and standards, environmental practices that are adjusted to different natural and industrial conditions in different parts of Canada.

The long-term efficiency of use of all of Canada's resources including energy resources, and economy and success in the maintenance of adequate environmental quality will require:

a) an effective program of land use in both undeveloped and developed areas;

b) a better understanding of environmental processes and ecological relationships in various parts of Canada;

c) a better understanding of demographic and social factors in Canada as they affect demands on energy; and

d) development of effective international environmental law.

THE COSTS FOR CANADA

The costs of preserving an adequate and acceptable standard of environmental quality, while production and consumption of energy continue to grow as expected, will be considerable in absolute terms, but small when expressed as a proportion of the total cost of energy expenditures. In the next decade or so, the most important additional costs for environmental protection, relative to present expenditures, will be incurred in the automobile and petroleum industries, and the electric power utilities. There will also be substantial costs incurred by the metallurgical, pulp and paper, and chemical industries, although these will include controls due to effects not directly connected with energy use. The subject is further discussed in Appx. A, Part 2.

It is estimated that the identifiable cost of environmental protection in the next ten years directly related to energy activities, to attain and preserve the national objectives for air and water quality, assuming the anticipated growth of energy production and use might be $7 to $10 billion. This cost is distributed as follows:

Transportation, and fuel used for transport (includes design changes, extra equipment, cost of reduced fuel efficiency, remedial or extraction processes)	$ 4 to 7 billion
Generation of power in stationary units (includes redesign, control devices and practices, rehabilitation of land; also includes $1.0 billion for desulphurization of oil and expenses for fuel switching, which would be applied to only 20 per cent of the total power generation capacity	$ 1.8 billion
Energy used for industrial and direct domestic purposes other than transport and power	0.7 billion
Environmental control within energy industries	0.5 billion
Total	$ 7 to $10 billion

This additional cost represents an increment of 5 to 7 per cent in the estimated total cost of energy production, distribution and use over the decade. These costs will of course be passed on to the consumer. It is clear, however, that if these estimates are of the right order of magnitude, the cost of control of environmental impacts and preservation of the quality of the environment will in itself not have a dominant effect on the cost and the pattern of use of energy in Canada.

Only a few (but important) industries experience energy costs which exceed 10 per cent of the average cost of their products. Thus an anticipated 7 per cent increase in energy costs due to environmental protection would seldom, by

itself, cause less than a 1-per-cent change in the average cost of goods. As far as energy activities are concerned, the cost of maintenance of environmental quality can not be expected to have a fundamental direct impact on the overall Canadian business scene. More important than the direct cost of environmental protection may be the economic effects of changes in behaviour patterns and goals of both industry and consumers. On the other hand, many analyses have shown the large potential net cost, both direct and indirect, to the nation if environmental quality is not maintained.

Implementation of Environmental Policies

Reduction or restriction of energy use is not an effective way to reduce or control unwanted changes in the environment. It would be impractical and indeed impossible to maintain a viable Canadian economy and to operate Canadian society as we know it with energy consumption reduced so low that environmental changes were negligible regardless of how the energy was produced or used.

What is required to maintain environmental quality is to avoid deleterious effects on the environment during energy production and use, while producing and using energy in the amounts needed by society. The avoidance of undesired environmental impacts should be primarily by proper design and selection of techniques and equipment, and by careful operating procedures; and where changes cannot be avoided, e.g. in the use of land, by an environmental awareness and control of all environmental consequences. An environmental awareness and desire for overall efficiency and maximum benefit to the quality of life will generally be consonant with the most effective use of non-renewable and renewble resources, but it must be remembered that control of the environmental effects of energy production and use itself may require expenditure of additional energy. Thus greater energy consumption may be associated with an environment of unimpaired quality rather than with one whose quality has been adversely affected by energy activities.

Present information suggests that an acceptable level of quality of environment, in vital areas of Canadian life can be reached and maintained without drastic changes in the pattern of energy supply and demand. Technology by which this can be accomplished is known, although in some areas there is much room for improvement in the effectiveness and economy. However, in order to achieve this goal it will be necessary to have:

- —national and international agreement and standards;
- —impartial and acceptable monitoring networks;
- —tough legislation and enforcement;
- —an economy that can sustain the increased short-term and middle-term costs without undue hardship on specific sectors of the population;
- —a practical and balanced program of long-term use of both non-renewable and renewable resources.

Failure may lead to much greater long-term costs and national economic or social hardship.

National and international objectives and standards for environmental quality may change in the future, with improved knowledge of the environmental conse-

quences of various activities, and of the nature and behaviour of the diverse natural environments in Canada. They will also be affected and possibly modified by changes in social values and economic conditions. From present information, however, it appears that the most stringent environmental standards likely to be set by Canada or international agencies could be met without causing a fundamental change in Canada's overall use of energy, although compliance could cause significant local adjustments. In some areas the cost might increase considerably.

The federal government has established national objectives for air and water quality for all of Canada, and together with the provinces is developing guidelines to reduce or control disturbance of terrain, or displacement or destruction of wildlife and indigenous vegetation. Within these national objectives and guidelines there is scope for a variety of choices of behaviour. Many of these choices will involve energy activities. Canada's energy policies must facilitate the making of these choices so that the national economy remains strong and diverse, the natural resources are used in the most effective manner, while at the same time the quality of the environment is maintained above the established national objectives.

The fundamental purpose of environmental regulations and standards must be to achieve and maintain a desired quality of environment rather than to regulate human or industrial activities. However, protection of environmental quality can in most cases only be achieved through control of polluting or disturbing activities. From the point of view of Canada's energy policies, this control should be as flexible as practical, always ensuring that national objectives of environmental quality are not violated. Control or regulation should take into account the following:

The provincial governments, which control natural resources and many aspects of industry, and whose legislation is an important factor in both energy activities and environmental management, must be able to determine the activities that best meet their objectives.

The public concepts of the trade-offs between economic, social and environmental objectives will vary in the short, medium, and longer terms, and will be different in different regions; to be effective, environmental control must be nationally consistent with regard to environmental quality, yet acceptable locally in each area.

The true net economy and long-term benefits accruing from proper design of equipment and techniques to avoid undesired environmental changes, as opposed to palliative remedial measures to counteract faulty design or methods; and consequently the desirability of encouraging investment in environmental control prior to construction or manufacture of energy-using facilities or equipment.

The advisability, under some circumstances, of implementing environmental control in a graduated or step-like fashion. Such a procedure must be used with caution, but it may be a means of applying the best practical technology in an area where control technology is evolving or improving, and it may be advisable in the case of older plants or in developing areas to enable activities to

"pay their way" and the economy to remain productive while ultimately achieving lasting environmental quality.

The need to weigh the direct economic savings resulting from standardization of energy-consuming capital goods or facilities against the true net cost of such standardization, in terms of resource use, and social, convenience, and environmental aspects.

The desirability in certain circumstances of adjusting environmental control at some locations to the natural seasonal or short-term variations in environmental conditions.

The synergistic or cumulative effects on the environment of various combinations of energy activities.

The Special Conditions in Canada

Several factors contribute to a distinctive situation in Canada regarding the relationship between energy and the environment, and the potential effectiveness of the environmental aspects of a national energy policy.

In comparison with present and likely future domestic demand, Canada has a large energy resource base supplied with those types of fuels which have the best potential for providing energy with minimum adverse impact on the environment. This fortunate situation allows Canada to apply and evaluate environmental policies in the use of energy in Canada with a minimum of constraints from trade policies or physical availability of supplies. On the other hand, Canada's energy resources are attractive in foreign markets, and conservation or environmental policies in other countries can have an important influence on the price and demand for Canadian energy materials.

The areas of most serious potential environmental damage from energy activities in Canada are relatively small, scattered, and separated by areas where the disturbance is less. Even our most adversely affected locations are not far, in regional terms, from healthy, natural land and sources of clean water. There is still a good opportunity for maintaining a reservoir of healthy natural recovery capacity near most sources of environmental disturbance in Canada. Our energy policies must preserve and build on this environmental advantage.

Canada still has large hinterland areas where landscape and ecosystems can be preserved nearly undisturbed, without handicapping the development of energy supplies, provided adequate land management policies are applied, and environmental management is made a strong and integral part of resource development. Few if any other countries have as great an opportunity to develop their country in harmony with Nature to achieve long-term prosperity. Perhaps few also still have as great a chance to make colossal blunders in managing their environment.

The large size of Canada in relation to its population, the distance between main settlements, and the seasonally fluctuating climate with a long period of biological dormancy and marked cold intervals requires Canadians to use more energy for basic transport, heating of houses and work areas, etc., than almost any other nation in order to achieve the same degree of social communication and material

standard of living. Most Canadians have chosen not to be frugal in their use of energy but to consider that the advantages of a high-energy life style are worth the cost of the energy. An increasingly important part of that cost is related to the environmental impact and the price that must be paid, more in behaviour and awareness than in dollars to mitigate it. Energy thus plays a role in Canadian society that may be relatively larger than in many other nations. Canadians individually are aware of its importance in making their environment liveable and of its potential for degrading environmental quality.

The Canadian climate, with the annual period of snow and ice cover, low temperature and low sunlight intensity, causes some pollutants to have a different behaviour or effect on physical and biological processes than they do in more southerly regions where liquid water is present throughout the year. In a similar manner, due to low temperatures and the presence of a seasonal, or in some places, year-round ice cover, the aquatic and marine environments within and near Canada will have distinctive behaviour and different sensibility to disturbance from those in warmer climates. Thus conclusions about the environmental effects of pollutants, as observed in other countries, may not apply directly to Canada. The environmental policies or regulations that have been developed in other nations may not have the same results in Canada. Although the differences will vary widely, on the whole, the Canadian environments are likely to be more susceptible to damage from energy activities than those in lower latitudes.

The most populous area of Canada is situated geographically so that at times its atmosphere and main watercourse may already be carrying pollutants from a highly industrialized part of the United States.

Canadian coastal industries and harbours, with their relatively high potential for marine or inshore pollution, are typically on sheltered waters, which are locally often naturally biologically prolific, and where water circulation is comparatively restricted. Thus pollution from activities on or near the Canadian coastline is apt to be concentrated where it could do the greatest environmental and economic damage.

The availability of abundant power, land space, and fresh water at comparatively low cost has enabled Canada to develop energy intensive industries that would not otherwise be profitable. These industries form an important part of our national economy. Their continued viability will depend increasingly on realistic and effective land-use and environmental management.

Canadian citizens commonly have a contradictory feeling about the environment. On the one hand they cherish the wild and "natural" attributes of the country, and on the other they feel a desire to conquer the wildness and to put it to use by man. These feelings influence the acceptability of environmental control measures connected with energy use.

Canada's energy dealings, domestic or foreign, are not of sufficient magnitude to have a controlling influence on world politics or world trade. Our energy resources, while large in Canadian terms, are insufficient to have a major effect on the energy problems of our chief foreign customer, the United States. Thus the environmental problems of energy use in other countries will affect the Cana-

dian market for energy and energy materials, but Canada's environmental policies are not likely to have a major effect on international relations.

Canadians benefit, both economically and in quality and range of available goods and activities using energy, from partial integration with the U.S. market and marketing system. Energy-using equipment and processes developed to conform with United States environmental standards are likely also to be used in Canada. The funds and investments needed to develop and market energy are influenced by the degree of integration with the U.S., and by the environmental concerns and actions in both countries. Canada's energy and environment policies must therefore take into account those of the United States.

The geographic, demographic, and cultural heterogeneity of Canada, and the heavy dependence on energy-consuming items that are designed or produced for use in other countries which may have different environmental situations and concerns, call for a wide range of solutions to energy-environment problems.

Effects of Energy Production and Use in Canada

Although most of Canada is still blessed with an environment whose quality is relatively unaffected by the results of energy production and use, some undesired effects are becoming apparent in nearly all settled areas. In our most heavily populated and industrialized regions—in the Great Lakes—St. Lawrence River corridor and the lower Fraser River Valley in particular—energy activities and products have contributed importantly to a deterioration of the quality of the natural environment in what are, in the business sense, among the wealthiest and most productive parts of Canada. In our sparsely settled and hinterland areas, also, energy-related activities have disturbed the terrain, placed stress on local ecosystems, and in some cases damaged or threatened the ability of the land to support and satisfy the culture of the local inhabitants.

Thus despite the large size of Canada in relation to its population and the relatively unspoiled natural state of much of the country, most Canadians in urban, rural and frontier areas, live in places where their environment has been affected adversely, or is in danger of being affected, by energy production and use.

The wide variety of ways in which the regional or local environment of Canada is affected or threatened by the multitude of activities connected with the production and use of energy in Canada are discussed in Appx. A, Part 2.

The national energy policy must facilitate, in cooperation with the provinces and industry, the long-term avoidance or reduction of undesired environmental effects and the maintenance of an acceptable and continuously improving quality of the environment.

The local or regional environment of Canada is affected or threatened in a wide variety of ways by the multitude of activities connected with the production and use of energy in Canada. Some of these are noted briefly in the Appendix A. The national energy policy must facilitate, in cooperation with the provinces and industry, the long-term reduction of undesired environmental effects and the maintenance of an acceptable and continuously improving quality of the environment.

The principal areas of concern and needed action are:

Continuing review and upgrading where appropriate of federal and provincial environmental regulations applicable to exploration, extraction, transport, processing and use of energy materials;

Continuing research into the physical and biological aspects and the ecological relationships of areas of Canada where energy materials are produced or used; including marine areas adjacent to Canada;

Continuing research into ways of lessening the undesired impact on the environment of activities connected with the exploration for energy materials, or the production and use of energy. Such research should include investigation of more effective ways of making beneficial use of the very large quantities of low-temperature "waste" heat produced by major energy activities;

Thorough "before" and "after" studies of the environmental situation in established energy development and energy-use installations, with public discussion of the results;

Formulation of comprehensive and effective programs for land use and for utilization of coastal, marine, and lacustrine areas, with public participation and discussion; and implementation of such programs, particularly in undeveloped regions, before development decisions are made or investments committed;

Identification of areas or zones where the terrestrial, aquatic or marine environment of Canada is particularly sensitive or where it is particularly desirable that disturbance of the ecosystem or physical environment be avoided; and the development of legal or administrative mechanisms to provide the required special protection.

Cooperation and exchange of data with industry and with other countries, especially the United States and the Soviet Union, on the characteristics of the environment that are affected by energy activities, and the effectiveness of methods to prevent or mitigate damage;

The public release of information on the environmental and possible social advantages and drawbacks, and the immediate and net long-term costs, of different alternatives in the production, transportation, and use of various fuels.

Canada's contribution to the real or potential impact on the global environment by human activities connected with energy production and use appears to be relatively small in world terms, but it is by no means negligible. As a country with a number of energy options and an advanced energy technology we have an obligation to take a leading part in ensuring that the energy activities of man do not in the long run make the world unfit for mankind. In particular Canada should:

Take effective national action and work vigorously for international action to reduce or prevent the discharge of petroleum products and radioactive materials into the oceans and atmosphere;

Participate in monitoring and research programs on the regional or global effects of combustion products and waste heat, with participation in developing an international action plan to control or mitigate harmful operations or effects when appropriate;

Avoid, within her territories, action or technological developments that are of questionable net social value or for which there are alternatives, if such actions carry an unknown or indeterminable environmental risk.

At the United Nations Conference on the Human Environment in Stockholm in 1972, Canada committed herself to work towards these ends. Our energy policy must help us to fulfill that commitment.

Environmental Quality and the Environmental Goals

The quality of our environment is quite a different thing from the characteristics of the natural environment itself. The natural environment of Canada varies widely, from the mild dampness of Vancouver Island to the windy harshness of Hudson Bay, from the grasslands of Alberta to the tidal flats of Fundy, from the Niagara farmlands to the bleak uplands of Baffin Island. Canadians in all parts of the country have a right to an environment whose quality is basically healthy, and in which the local ecosystem, including people as part of it, can operate in a balanced manner. That quality will be determined very largely by the degree to which the composition of the air and water in the region is maintained and renewed by natural processes, and by the extent to which the landscape and biological cycles are able to develop and function in harmony with the climate and geology.

Contrary to what may be sometimes incorrectly assumed, a high quality environment does not imply or require an environment unchanged from that which was present before human settlement, or a primitive situation in which Man is absent or insignificant. Well-managed farms or industrial areas can operate in, and indeed contribute to regional environments of as high quality as "untouched" natural land. What is important is not the presence or absence of human impact but whether human activities are carried on in harmony with nature. In this process, Man's use of energy and disposal of its waste products are critical.

The Government of Canada has established national objectives for environmental quality which apply to all parts of the country. If these objectives can be met and maintained, all Canadians will be able to enjoy, and to continue to enjoy, a healthful and satisfying physical environment. National energy policies, as such, cannot set up detailed environmental regulations to be applied indiscriminately in all parts of Canada, but must set forth a consistent philosophy and set of objectives, compatible with the national environmental objectives and the provincial and federal regulations, under which detailed policies or rules appropriate to specific regions or activities can be applied.

Successful national energy policies must therefore integrate environmental factors with the economic and social factors to provide adequate energy for all Canadians in a natural and social environment that is and continues to be acceptable, productive and satisfying in every part of Canada.

A basic goal of national energy policies should be supporting or facilitating environmental practices which will achieve an acceptable environment in every part of Canada, and then maintaining that quality of environment regardless of the amount of energy produced or used. To achieve this goal will require that:

The total mass of air pollutants in any region shall be within recommended Canadian and international air quality standards;

Canada's flora and fauna should not be endangered by energy activities, except where with knowledge and participation of biological and environmental authorities the consequences and benefits are weighed beforehand;

Canadian landscapes and coastal areas will not be significantly disturbed by energy activities, except where the environmental change is planned and controlled;

Release of radioactivity should not exceed amounts presently anticipated and internationally accepted;

Oil discharge into the ocean will be reduced from what it is at present and held at a low rate;

In any local area pollution or adverse effects from any energy activity will not reach levels dangerous to human health.

With proper technology, and guided by appropriate government policy, all of this can be achieved at costs that are not disruptive to the economy. Further research and technological development will reduce the costs of environmental protection, and enhance the ability of Canadians to have adequate available energy and a high quality environment. In achieving this goal national energy policies will contribute importantly to long-lasting Canadian prosperity in its truest sense.

AN ENERGY POLICY FOR CANADA

PHASE 1

VOLUME II - APPENDICES

AN ENERGY POLICY FOR CANADA –Phase 1

Volume II. APPENDICES

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APPENDIX A

PART 1. ENERGY REQUIREMENTS AND RESOURCES

Chapter 1

CANADA'S ENERGY REQUIREMENTS

A "standard forecast" of Canada's energy requirements to the year 2000 has been derived on a sector-by-sector basis for the various principal energy sources. This forecast suggests that total secondary energy demand could increase from a level of about 5,000 trillion Btu in 1970 to about 20,200 trillion Btu by the year 2000, a four-fold increase. Petroleum and natural gas could still be meeting 79 per cent of total energy requirements in the year 2000.

The standard forecast is an aggregation of forecasts made separately for each major sector of the economy based on the relationships of energy consumption within that sector to obvious relevant parameters. The sector forecasts are generally related to a single population forecast and no attempt has been made to relate energy consumption to overall economic growth. The analysis consists of the following three separate stages:

First, the energy requirements for each energy consuming sector were determined. The aggregation of the individual sectors resulted in a *standard forecast* of both primary and secondary energy demand.

Second, a study was made to determine how changes in *population and economic growth* could influence the standard forecast.

Finally, various other factors which could influence the sector forecasts were studied. This resulted in the development of a number of *variations* based on the recognition that energy use could vary within wide limits as a result of changes in the structure of society, changes in government policies, changes in technology, and general attitudes towards energy conservation.

STANDARD FORECAST OF ENERGY REQUIREMENTS

An effort was made to develop a "neutral" standard forecast based on a number of assumptions, the most important of which is that there will be no major changes in existing government policies. This approach permits an appreciation of the probable impact of continuing present policies and attitudes towards energy and also allows the effect of major policy changes to be measured.

It was assumed that Canadian energy policies will evolve with the changes expected in Canada's energy supply situation over the next twenty years. During this period the energy supply emphasis will probably shift from hydroelectric energy and Western Canada oil and gas, to nuclear energy and petroleum from the Arctic and offshore areas. This shift will be caused by two factors: a depletion

of conventional western Canadian petroleum reserves accompanied by rapidly rising international petroleum prices, and the further development of nuclear technology. Such a shift would likely render certain cornerstones of present Canadian energy policies obsolete. For example, if Canada's east coast is able to produce significant amounts of oil and gas, the Ottawa Valley line might no longer be relevant.

The other basic assumptions of the standard forecast are outlined below:

It was assumed that the general political situation in the world would remain relatively stable.

It was assumed that the Canadian economy would continue to grow, with an ever-increasing share of the population being employed in the service industries.

It was assumed that government policy would reflect increasing concern about the environment.

It was assumed that the population of Canada would grow from about 21 million people in 5½ million households to about 35 million people in 10 million households by the year 2000. (See Tables 1 and 2.)

TABLE 1

POPULATION ESTIMATES

(*in thousands*)

	1966	1975	1980	1985	1990	1995	2000
Atlantic Provinces	1,975	2,071	2,127	2,186	2,248	2,311	2,377
Quebec	5,781	6,320	6,642	6,981	7,337	7,711	8,104
Ontario	6,961	8,553	9,537	10,586	11,687	12,844	14,038
Prairie Provinces	3,381	3,713	3,929	4,164	4,410	4,663	4,926
British Columbia, Yukon, & Northwest Territories	1,917	2,571	3,011	3,509	4,068	4,542	5,218
Canada	20,015	23,228	25,246	27,426	29,750	32,071	34,663

SOURCE: 1966 DBS Census Forecast: NEB staff estimate.

TABLE 2

HOUSEHOLDS OR OCCUPIED DWELLINGS

(*in thousands*)

	1966	1975	1980	1985	1990	1995	2000
Atlantic Provinces	449.0	483.4	507.8	535.1	564.8	596.6	631.6
Quebec	1,389.0	1,656.6	1,834.2	1,953.8	2,081.4	2,217.7	2,363.3
Ontario	1,877.0	2,428.4	2,790.2	3,144.9	3,472.0	3,815.8	4,170.5
Prairie Provinces	913.0	1,016.0	1,084.3	1,159.0	1,238.3	1,320.9	1,407.8
British Columbia, Yukon, & Northwest Territories	552.0	743.3	872.2	1,018.3	1,182.9	1,323.3	1,523.4
Canada	5,180.0	6,327.7	7,088.7	7,811.1	8,539.4	9,274.3	10,096.6

SOURCE: 1966 DBS Census Forecast: NEB staff estimate.

A number of important assumptions were also made with regard to the development of prices for various energy sources and these were translated into consumption patterns in the various sectors. The future price developments are described in more detail in the main document, but for convenience the major assumptions are repeated here:

> Electricity costs are not likely to exceed 7 or 8 mills per kWh (in 1972 dollars) by the year 2000. Lower costs resulting from both a "learning curve effect" and future economics of scale in the construction of nuclear power stations are expected to offset real cost increases.
>
> International crude oil prices will determine Canadian prices. The delivered prices on the Atlantic coast will increase from about \$3.00 at present to \$4.50 in 1980, \$6.50 in 1990 and \$7.00 in the year 2000 (all in 1972 dollars).
>
> Natural gas will be priced competitively with oil in the Great Lakes area, taking the premium value or form value of this clean fuel into account. City gate prices of 2½ to 3 times present prices are assumed in the late 1980's.
>
> Coal prices for thermal generation will be competitive with fuel oil. Metallurgical coal will cost from \$22 to \$25 per ton in 1980.

As explained in the main report, large volumes of gas are expected to be available at prices of about \$1.25 per Mcf. At these prices, the production of natural gas is considered to be economic on the east coast, the Arctic Islands and in the Mackenzie Delta. The assumption of a natural gas supply push from the early eighties onwards has been used in the development of the various estimates in the standard forecast.

In essence these assumptions mean that Canadian energy prices will be largely set by international prices. If measures were taken to insulate Canadian consumers from the upward pressure of world prices, the effect on the demand projections would vary depending upon the energy form being considered, but the overall effect would be an upward movement of demand.

The standard forecast is essentially a *sector forecast*. Forecasts for each sector were made separately, based on the relationships of energy use to obvious parameters. For example, home heating requirements were related to the number and size of homes and gasoline consumption was related to the number of cars and miles driven. Although the forecasts made in the sectors were in general based on the same population forecasts, no attempt was made to relate energy consumption to overall economic growth.

One of the main drawbacks of the sector analysis becomes obvious in the above discussion. Since the forecasts are made individually, the projections of the various sectors could be inconsistent from a general economic point of view. For example, the forecast of energy requirements for the iron and steel industry could be based on implicit, unquantified assumptions about the development of the GNP, or on a specific performance expectation of the Canadian export industries. These assumptions could be inconsistent with those in other sectors, such as the implicit notion of the development of GNP used in estimating the number of cars per person in the year 2000. Although this lack of overall economic consistency is

a drawback, it must be remembered that it is difficult, if not impossible, to make meaningful overall economic assumptions about the Canadian society in the year 2000. At the moment, it is also impossible to relate (meaningfully) energy consumption to overall economic growth in the future.

The advantage of a sector forecast is that it gives excellent insight into the possible structural development of energy demand and supply. The standard forecast based on this analysis permits a study of the impact of various policy measures. Using a sector forecast, energy policy can be related to other policies such as urban policy, transport policy and industrial policy.

The estimates for each sector are based on actual end use of energy in that sector. Consequently, the electricity sector is not considered to be an end-use sector but only a conversion sector. The end-use sectors are: the residential sector, the commercial sector, the transport sector, the industrial sector, the energy supply industry sector, and the non-energy use sector. This last sector includes all fuels not used for energy purposes, such as natural gas and naphtha used as petrochemical feedstocks, and oil products used as lubricants, asphalts, etc.

These sectors are directly comparable with those published by Statistics Canada in their publication "Detailed Energy Supply and Demand 1958-1969" (57-505). Care was taken throughout the analysis to ensure that all figures would be directly comparable with those in this publication. The same conversion factors were used to convert natural units such as barrels of oil, or tons of coal, into Btu's. The same five regions of Canada were used in geographical breakdowns where necessary. Small adaptions were made in the energy balance to include various new energy sources such as nuclear energy. These adaptions will be discussed later. This publication by Statistics Canada is essential background information for those who want to make a detailed study of this forecast.

The standard forecast of secondary energy demand is presented on a sector-by-sector basis for 1980, 1990 and 2000 in Tables 9, 10 and 11. These tables also contain estimates of primary energy supply and supply/demand balances. A summary of the standard forecast is contained in Table 14 along with estimates of how the secondary energy demand will be allocated among various energy sources. Table 14 is the forecast used in the main report to compare possible supply/demand relationships.

The Residential Sector

The estimation of residential energy use was developed in two sections; fuel and electricity use for heating purposes, and electricity use for non-heating purposes.

Home Heating Requirements. The amount of energy used in Canada for home heating purposes is a function of the prevailing climatic conditions, the particular fuel used, and the type and size of dwellings. The diverse nature of these factors as they exist throughout Canada necessitates consideration of each on a regional basis.

In general, there exists a direct relationship between the number of degree days in a region, and the amount of energy used per household for heating purposes in that region. Table 3 contains the calculated energy consumption per household, derived from this relationship, for the various regions in Canada.

TABLE 3

AVERAGE ANNUAL ENERGY USE FOR HEATING PURPOSES PER HOUSEHOLD PER YEAR (1958–1969)

(*millions of Btu's*)

Atlantic Provinces	172
Quebec	154
Ontario	150
Prairie Provinces	187
B.C., Yukon, N.W.T.	116
Canada	158

The average energy consumption per household has remained virtually constant throughout the previous decade in all the five regions in Canada. There is undoubtedly a trend towards increasing spaciousness of the average dwelling unit, increasing heating comfort standards and an increasing number of families with more than one home, all of which would tend to increase energy consumption. Two important trends that have moderated energy consumption in the past are the trend towards the substitution of higher efficiency fuels for low efficiency fuels and the trend towards a higher number of apartments. As can be seen from Table 4, between 1958-1969, wood and coal were replaced as important heating fuels by oil products and natural gas. Natural gas is a more efficient fuel for home heating purposes than fuel oil, while fuel oil in turn, is more efficient than coal. The expected increase of natural gas and the further decline of coal for home heating purposes will continue to moderate the growth of primary energy demand. The trend towards urbanization of our society with the associated higher ratio of apartment units to single dwelling units results in a lower fuel use per household. It is estimated that these two trends will offset one another to a large extent and that the basic trend of the past decade will continue in the future; i.e. energy consumption per household will remain constant as far as heating needs are concerned.

TABLE 4

RESIDENTIAL ENERGY USE IN CANADA FOR HOME HEATING

(*trillion Btu's*)

	1958*	1969	1980	1990	2000
Coal	124	19	10	5	2
Oil products and LPG	376	602	605	487	408
Gas	80	231	439	665	906
Electricity for heating	—	8	38	88	169
Total	580	860	1,082	1,245	1,485

*Note: In 1958 about 60 trillion Btu from wood was used for home heating (not included in this table).

The total energy requirement for each region in Canada was calculated by multiplying the number of households (as given in Table 2) by the energy requirements (given in Table 3) for various years in the future. The distribution of the overall heating requirements among the various fuels was established by a number of successive steps.

The first step was to estimate the total Canadian use of coal in the residential sector. Coal requirements declined drastically during the 1960's, and it is expected that this decline will continue since coal prices for home heating purposes are forecast to increase faster than other fuel prices. In view of the relatively small volumes involved, arbitrary quantities were set as follows: 10 trillion Btu in 1980, 5 trillion Btu in 1990, and 2 trillion Btu in 2000.

The second step was to estimate electricity requirements for home heating purposes. Although the use of electricity covers presently only a small proportion of the home heating requirements, a rather rapid penetration of this sector is expected. This will occur not only because of advantages inherent in heating electrically such as, more basement space, less noise, less dust, and better climate control on a per room basis, but also because of expected economic advantages resulting from more stable prices for electricity in the future as compared with increasing prices for light fuel oil and natural gas.

The remainder of the fuel used for home heating is composed of liquid and gaseous fuels. Natural gas is assumed to further penetrate the home heating market in Ontario, British Columbia, and the Prairies at a gradual rate, and to penetrate the market in the Atlantic Provinces and Quebec at a rapid rate. The rapid penetration of the Atlantic region will be caused by the availability of commercially attractive gas being produced from the Atlantic shelf. If this production does not occur then the penetration rate will be considerably less. This uncertainty contributes to the ranges given in the total oil and gas demand estimates of the main report.

It is assumed that demand for L.P.G. will constitute 7% of the total demand for liquid fuels, the remainder being light fuel oil. It is expected that furnace efficiencies for light fuel oil will increase from 72% in 1980 to 80% in 1990 and 2000, therefore fuel oil requirements will be modified accordingly.

Electricity Demand. Electricity consumption per household for non-heating purposes is expected to more than double over the period 1960 to 1980. This trend is expected to slow down only slightly in the period 1980 to 2000. Table 5 gives more detailed information. The anticipated stable level of electricity prices in real terms will not stem the growth of energy required by appliances in the average Canadian home unless, as earlier noted, there are major changes in the policies of governments at various levels. The average use of 17,500 kWh per household in the year 2000 can be equated with the consumption of an arbitrary list of appliances, and would be sufficient to satisfy the energy requirements of a stove, a water heater, a fridge, a freezer, two T.V.'s, a washer and dryer, a dishwasher, and a large number of smaller appliances and lighting fixtures under conditions of average use.

TABLE 5

RESIDENTIAL ELECTRICITY USE

	1966	1980	1990	2000
Total (10^9 kWh)	32	81	138	226
Home heating (10^9 kWh)	1	11	36	49
All other electricity use (10^9 kWh)	31	70	112	177
Per household use of electricity other than home heating (10^3 kWh)	6.0	9.9	13.1	17.5

The Commercial Sector

Statistics Canada Publication 57-505 shows the average yearly growth figure of energy consumption in the commercial sector for the period 1958 to 1969 to be slightly higher than 12% per year.

There are problems with the classification of the commercial sector. For instance, some of the natural gas that is consumed in apartment complexes and purchased at commercial rates is included in the commercial sector instead of the residential sector. Large commercial users paying industrial rates may be included in the industrial sector. Also, some industrial establishments will actually pay commercial rates and be included in the commercial sector. Electricity consumed by mass transport systems such as subways, trolley buses, is also included in the commercial sector instead of the transport sector. Finally, all oil products that are used for "other purposes" are included in this sector even though they are consumed partially for industrial purposes.

The second problem is that the heterogeneous nature of this sector precludes the use of any straightforward extrapolation technique. The commercial sector includes heating requirements for schools, churches, stores, office buildings, and buildings for various service activities, such as real estate firms, banks, hotels, restaurants, airports, etc. It also includes fuel use for purposes other than climate control, such as water heating in launderettes, and electricity use for a wide variety of purposes.

The rapid growth of energy use in the commercial sector is related to the rapid growth of the service sector in our society. Employment in the service sector increased over the period 1961-1968 by more than 1 million people (from 2.9-4.0 million people). Presently 60% of the labour force is employed in service industries. This proportion is expected to grow to 80% in the long-term future.

Energy use is also related to the rapid increase in building activity in the commercial sector. Over the last ten years, the volume of building space in the commercial sector increased from about 10 billion cubic feet to 17 billion cubic feet.

It is not expected that energy use in the commercial sector will grow at the same rate as in the past. Estimates resulted in a forecast of a yearly growth of 9% in this decade, 6% throughout the 1980's and 4% throughout the 1990's.

The share of electricity in the total demand of this sector has increased slightly in the past. Given the price conditions expected for the future, this trend

is expected to become more pronounced. Electric heating of large office buildings will become more attractive, while at the same time air conditioning and other important electricity consumption patterns will develop strongly. More detailed information is given in Table 6.

TABLE 6

ENERGY USE IN THE COMMERCIAL SECTOR
(*trillion Btu's*)

	1958	1969	1980	1990	2000
Coal	40	15	8	4	0
Oil	72	330	706	846	874
Gas	38	182	554	1,269	2,038
Electricity, heat	36	131	423	908	1,573
Total	186	658	1,691	3,027	4,485

The Industrial Sector

The analysis of energy demand in the industrial sector is based on separate forecasts for each of the following industry groups: the pulp and paper industry, the chemical industries, the iron and steel industry, the metal smelting and refining industries, and all other industries.

Pulp and Paper. The pulp and paper industry is the largest industrial consumer of energy in Canada today. It accounts for 23% of all the energy consumed in this sector. Future energy consumption in the pulp and paper industry depends largely on the development of the export market. In the future, the growth rate of the export market might well decline as a result of factors such as increased recycling of paper in the U.S., development of synthetic paper, and fast growing hybrid trees. The limited use of wood was not included in our projection, but the effects of electricity generation and steam production in the pulp and paper industry as a combined process is taken into account by allocating part of the "conversion losses" to the pulp and paper industry.

The Chemical Industry. The chemical industry is expected to grow very rapidly. It is, however, rather difficult to forecast the energy use for this sector, because technological change and various industrial development patterns might heavily influence its growth. "Industrial chemicals" consume about 85% of the energy in the chemical sector. Other chemical industries such as plastics and resins, fertilizers, pharmaceuticals, paint and varnish, consume the remainder. In the chemical industry, large volumes of energy products are not directly consumed as energy, but are used as raw material in the manufacture of other products. These non-energy uses will be dealt with later in this Appendix.

The Iron and Steel Industry. It is generally expected that Canadian steel production will grow at a rate between 3-3½% per year. However, changes will occur in the methods of steel production. In 1971, 72% of Canadian steel was produced in open hearth furnaces, 33% in basic oxygen furnaces, and 15% in electric furnaces.

By the year 2000, it is expected that 75% of the steel production will use the basic oxygen method and 25% will be produced in electric furnaces using either scrap or some form of directly reduced iron ore. The energy needs of the iron and steel industry were determined on the basis of these forecasts. A heavy reliance on coke in the long term future remains the probable pattern.

Metal Smelting and Refining. The most important metal smelting and refining industry is the aluminum production industry. In the past, the aluminum industry has grown rather rapidly because of access to important export markets. However, it is assumed that in the future the growth of the aluminum industry will be limited by the growth of Canadian consumption of its products as fewer exports will occur. The growth of aluminum consumption in Canada is estimated to be 5% per year. Other types of smelting industries such as nickel, copper, lead and zinc smelting will continue to grow. It is expected that nickel, copper and lead production will have grown by a factor of 4 and zinc by a factor of 2 by the year 2000.

Other Industries. There are a number of other industries which are important energy consumers, such as the cement production industry, the motor vehicle manufacturing industry, sectors of the mining industry and the food and beverage industries. In 1969, the "other industries" taken together consumed 45% of the total fuels and 24% of the total electricity used by the industrial sector. Studies of these other industries indicate that this relationship will continue in the coming decade. This relationship was used for the projection until the year 2000. The results are given in Table 7.

TABLE 7

ENERGY USE IN INDUSTRIAL SECTOR

(trillions of Btu's)

	1958	1969	1980	1990	2000
Coal and coke	303	226	235	257	310
Oil	186	380	410	623	950
Gas	83	405	854	1,320	1,640
Electricity, heat	194	322	557	847	1,295
Total	766	1,333	2,057	3,047	4,195
Four sectors*:	—	763	1,202	1,716	2,471
Other sectors:	—	551	855	1,331	1,724

* Note: The four sectors are the pulp and paper industry, the chemical industry, the iron and steel industry, and the metal smelting and refining industry.

Future Trends. The historic share of the total energy requirements held by electricity has been approximately 25%. This will increase somewhat in the future with expected developments in the chemical industries and with expected stable price levels. Natural gas has penetrated the Ontario industrial fuels market rapidly in the last few years causing fuel oil consumption to remain constant in a growing market. If gas can be made available from the east coast offshore areas by 1978, it would likely be absorbed rapidly by some important industrial users. This would

cause a drop in the fuel oil share of the market by 1980. However, the fuel oil share would likely recover due to the expected strong increase in natural gas prices in the 1980's. It is expected that the demand for metallurgical coal will continue to increase gradually, and that this trend will no longer be offset by the declining use of thermal coal in this sector.

The Transport Sector

Gasoline consumption in automobile transport represents by far the largest portion of this demand sector. Future gasoline consumption by automobiles was estimated by using the same population estimate as used for the residential sector and by estimating the automobile-population ratio and yearly gasoline consumption per automobile. The automobile-population ratio was estimated to increase from its current level of about 0.35 to 0.43 by 1980, 0.46 in 1990 and 0.47 in the year 2000. Gasoline consumption per automobile was assumed to remain constant at 700 gallons per year, reflecting the compensating effects of more stringent environmental control regulations and a move towards smaller cars as a result of increasing gasoline prices.

The significant increase in the air transport market reflects not only a very large increase in personal air travel but also the increasing importance of air cargo transport.

In the standard forecast, no specific consideration was given to revolutionary developments in the transport sector.

Table 8 provides a breakdown of the historic consumption pattern in the transport market along with an estimate of demand for the years 1980, 1990 and 2000.

TABLE 8

ENERGY USE IN THE TRANSPORT MARKET
(trillion Btu's)

	1958	1969	1980	1990	2000
Road	496	871	1,570	2,144	2,865
Rail	127	84	100	141	199
Air	40	90	280	610	1,150
Marine	72	101	140	191	257
Total	735	1,146	2,090	3,086	4,471

THE ENERGY BALANCE

The Energy Balance was developed as a method of relating the secondary energy demand for each type of energy from each of the end-use sectors to the type and quantity of primary energy supplies required to satisfy that demand. The Energy Balance allows the estimation of total future energy resource requirements in an integrated way, accounting for changes in conversion efficiencies brought about by the effects of inter-fuel competition in the secondary market. Balance between

primary energy supply and secondary energy demand is achieved by the recognition of various conversion losses and waste.

The energy balances for 1980, 1990 and 2000 are given in Tables 9, 10 and 11. These tables are similar to those published by Statistics Canada (57-505). They have been simplified considerably, however, by omission of a number of energy supply-demand categories and by aggregating product headings. "Coke" and "Petroleum Coke" were grouped together as "Solid Products", "Coke Oven Gas" became "Gaseous Products" and "LPG" and "Crude Oil" were grouped. All other oil products except petroleum coke were grouped together as "Liquid Products".

The major elements of these energy balances are outlined below.

Energy Supply Industries

The energy supply industries consume some of their own products and have, therefore, been included as an end-use sector. Historically, the coal producing sector has used somewhat less than 1% of its production to operate coal mines and associated activities. This figure was used in Tables 9, 10 and 11 (Column 1, line 26).

Refineries use a considerable amount of energy to convert crude oil into a wide range of products. In Canada, this refinery use has been 7% of refinery output of liquid products. Column 3 includes products consumed in the conversion of oil sands to synthetic oil in the processing plants. This use is equal to 25% of the output of oil sands processing plants. This column also includes oil pipeline use and the use of LPG.

Natural gas use by the energy supply industries falls into two main categories: the use of natural gas for gas processing, and compressor fuel for the transport of gas by pipelines. Gas processing shrinkage was assumed to average 8% for all the future years. Pipeline use was estimated to be 5% of production from the east coast and the western provinces. For the Arctic areas, this percentage is considerably higher. It was estimated that 11% of Mackenzie Valley gas production will be used for transportation and about 17% of the Arctic Islands gas will be consumed for transport purposes.

Energy use by the electricity industries is largely related to losses in electricity transmission networks. These losses were estimated at 9% in 1980, 8% in 1990, and 7% of total electricity demand in the year 2000.

Waste

The term waste is used in this energy balance from a purely physical point of view. In most cases waste is inherent in the physical process of transforming fuels into electricity. This does not imply waste of resources from an economic point of view, because, in most cases, energy is produced and converted in the most efficient way possible based on current technology.

Small amounts of waste occur in coal transport and distribution, and in oil transport and distribution. Waste of natural gas in significant amounts is likely to occur with frontier development. Natural gas is always produced in conjunction with oil and is often not economically recoverable either as pipeline gas or for

reinjection into the producing reservoir. Under these circumstances, it is flared. Currently, flaring amounts to only a few per cent of total gas production because gas pipeline networks are available virtually everywhere in the gas producing provinces. However, when oil production in the frontier areas begins, it is likely that increased flaring will occur.

The largest component of waste results from losses during energy conversion processes. The figure given in Column 10, line 25(b), (Tables 9, 10 and 11), is the total calculated conversion loss minus the fraction that is recovered, usually as "waste heat". The inclusion of waste and conversion losses allows the energy balance to provide an insight into the amount of waste heat that will be produced by the energy economy.

Total Supply

Once the net final consumption in the economy (lines 27-34) has been calculated, it is possible to calculate the total use by final consumers by adding the use by the energy supply industries. The total use plus waste then must equal the total supply. It is this total supply that must be made available by the energy industries and the energy balance thus "balances" around the line 25(a).

Conversion of Energy

Shown in Tables 9, 10 and 11, lines 8/9, 10/11, and 22/23, is the process of conversion of energy. In the standard forecast, three main types of conversion were considered: the conversion of coal to coal products, the conversion of crude oil to liquid products and the conversion of various fuels to electricity. In the conversion from coal to coke, it was assumed on the basis of a previous study by Statistics Canada, that the conversion losses would be roughly 10% of the input. The remaining 90% is converted in the following proportions: 70% coke and 20% coke oven gas.

It is difficult to distinguish, for statistical purposes, between the refineries own use and possible conversion losses. Therefore, any conversion losses which might occur during petroleum refining are included in line 26 under the heading "energy supply industries."

The conversion of energy sources to electricity results in the largest conversion losses. In converting the hydro potential in Canada to electricity, conversion losses occur that could be as high as 20% of the original hydro potential. These conversion losses, however, are not included in this table. In all other cases conversion losses are included.

The efficiency of nuclear reactors is assumed to be 30% in 1980, 32% in 1990, and 34% in the year 2000. The efficiencies for the conversion of natural gas to electricity are estimated to be 30% in 1980 and 1990, and 33% in the year 2000. The average efficiency of coal-fired plants for Canada was estimated to be 33% in 1980, 35% in 1990, and 37% in the year 2000, with most of these plants being located on the Prairies. Fuel oil will be burned mainly in areas where fuel oil costs are already relatively high, thereby providing the economic incentive for higher efficiencies. Efficiencies are estimated as 34% in 1980, 36% in 1990, and 38% in the year 2000. The efficiency of generation by the solid waste disposal industry is estimated at 25%.

TABLE 9

CANADA ENERGY SUPPLY-DEMAND BALANCE FOR THE YEAR 1980

(*All figures in trillions of Btu's*)[1]

	Coal	Solid Products	Crude oil LPG tarsand oil NGL	Liquid Products	Natural Gas	Gaseous Products	Total Fuels	Hydro-power Electricity	Heat Nuclear Power	Other Energy Sources	Con-version Losses	Total
	1	2	3	4	5	6	(1/6)	7	8	9	10	(1/10)
7. availability	1,138	—	4,948	—	2,971	—	9,057	802	510	12	—	10,381
8/9 a. converted to electricity	785	—	—	—	127	—	912	—	510	12	—	1,434
b. production of electricity and waste	—	—	—	—	—	—	—	453[3]	—	—	981	1,434
10/11 a. converted to other products	247	—	4,650	—	0	—	4,897	—	—	—	—	4,897
b. production of other products and waste	—	213	—	4,610	—	49	4,872	—	—	—	25	4,897
22/23 a. products converted to electricity	—	—	—	282	—	—	282	—	—	—	—	282
b. production of electricity and waste	—	—	—	—	—	—	—	96	—	—	186	282
25. a. total supply	106	213	298	4,328	2,844	49	7,838	1,351			1,192	10,381
b. waste	10	2	3	0	400	0	415	0			1,162	1,577
c. total use	96	211	295	4,328	2,444	49	7,423	1,351			30	8,804

26. energy supply industries	10	0	215	302	600	0	1,127	122		1,234
Transportation	4	0	0	2,090	0	0	2,094	0		2,094
27. road				1,570						
28. rail				100						
29. air				280						
30. marine				140						
31. domestic and farm	10	0	42	563	439	0	1,054	276	3	1,333
32. commercial	8	0	0	706	554	0	1,268	423		1,691
33. industrial	64	171	12	398	806	49	1,500	530	27	2,057
34. non-energy use[2]	0	40	26	269	45	0	380	0	0	386

[1]NOTE: The numbers in this table are given in trillions of Btu's. This is, however, not an indication of a degree of exactitude. Considerable uncertainty exists about most of these numbers.

[2]Non-energy use includes more products in this table than in Publication 57-505 of Statistics Canada.

[3]This figure is composed of 153 nuclear, 38 natural gas, 259 coal, and 3 other.

TABLE 10

CANADA ENERGY SUPPLY-DEMAND BALANCE FOR THE YEAR 1990

(All figures in trillions of Btu's)

	Coal	Solid Products	Crude oil LPG tarsand oil NGL	Liquid Products	Natural Gas	Gaseous Products	Total Fuels	Hydro-power Electricity	Heat Nuclear Power	Other Energy Sources	Con-version Losses	Total
	1	2	3	4	5	6	(1/6)	7	8	9	10	(1/10)
7. availability	1,626	—	7,519	—	5,175	—	14,320	1,057	1,919	40		17,336
8/9 a. converted to electricity	1,238	—	—	—	103	—	1,341	—	1,919	40	—	3,300
b. production of electricity and waste	—	—	—	—	—	—	—	1,088[3]			2,212	3,300
10/11 a. converted to other products	312	—	6,503	—	—	—	6,912	—	—		—	6,912
b. production of other products and waste	—	278	—	6,443	—	63	6,882	—			31	6,912
22/23 a. products converted to electricity	—	—	—	653	—	—	653	—	—	—		653
b. production of electricity and waste	—	—	—	—	—	—	—	235	—	—	418	653
25. a. total supply	76	278	1,016	5,790	5,072	63	12,295	2,380			2,661	17,336
b. waste	10	2	3	0	500	0	515	0			2,619	3,134
c. total use	66	276	1,013	5,790	4,572	63	11,780	2,380			42	14,202

26. energy supply industries	15	0	920	420	1,300	0	2,637	190		2,827
Transportation	1	0	0	3,086	0	0	3,087	0		3,087
27. road				2,144						
28. rail				141						
29. air				610						
30. marine	1			191						
31. domestic and farm	5	0	39	448	665	0	1,157	472	5	1,634
32. commercial	4	0	0	846	1,269	0	2,119	908	0	3,027
33. industrial	41	216	19	604	1,257	63	2,200	810	37	3,047
34. non-energy use[2]	0	60	35	404	81	0	580	0		580

[2]Non-energy use includes more products in this table than in Publication 57-505 of Statistics Canada.
[3]This figure is composed of 614 nuclear, 31 natural gas, 433 coal, 10 other.

TABLE 11

CANADA ENERGY SUPPLY-DEMAND BALANCE FOR THE YEAR 2000

(All figures in trillions of Btu's)

	Coal	Solid Products	Crude oil LPG tarsand oil NGL	Liquid Products	Natural Gas	Gaseous Products	Total Fuels	Hydro-power Electricity	Heat Nuclear Power	Other Energy Sources	Con-version Losses	Total
	1	2	3	4	5	6	(1/6)	7	8	9	10	(1/10)
7. availability	1,861		10,153	—	7,423	—	19,437	1,174	5,037	80		25,728
8/9 a. converted to electricity	1,392				176	—	1,568	—	5,037	80	—	6,685
b. production of electricity and waste	—	—	—	—	—	—	—	2,305[3]			4,380	6,685
10/11 a. converted to other products	417	—	8,814	—	—	—	9,386				—	9,386
b. production of other products and waste	—	379	—	8,727	—	83	9,344				42	9,386
22/23 a. products converted to electricity	—	—	—	1,005	—	—	1,005					1,005
b. production of electricity and waste	—	—	—	—	—	—	—	382			623	1,160
25. a. total supply	52	379	1,339	7,722	7,247	83	16,822	3,861			5,045	25,728
b. waste	10	2	3	—	500	—	515	—			4,985	5,500
c. total use	42	377	1,336	7,722	6,747	83	16,307	3,861			60	20,228

26. energy supply industries	20	0	1,227	540	2,100	0	3,887	270		4,157
Transportation	0	0	0	4,471	0	0	4,471	0		4,471
27. road				2,865						
28. rail				199						
29. air				1,150						
30. marine				257						
31. domestic and farm	2	0	32	376	906	0	1,316	773	10	2,099
32. commercial	0	0	0	874	2,038	0	2,912	1,568	5	4,485
33. industrial	20	290	30	920	1,557	83	2,900	1,250	45	4,195
34. non-energy use[2]	0	87	47	541	146	0	821	0		821

[2]Non-energy use includes more products in this table than in Publication 57-505 of Statistics Canada.
[3]This figure is composed of 1,712 nuclear, 58 natural gas, 515 coal, 20 other.

Electricity

The forecast of the contribution of each of the various energy sources to the total generation of electricity is of fundamental importance. Inter-energy competition is strong in this market. It was estimated that the solid waste industries could provide 12 trillion Btu's input in 1980, 40 trillion Btu's in 1990, and 80 trillion Btu's in the year 2000. However, this is a rather insignificant amount in comparison with total requirements.

The share which each of the other energy sources would capture in the generation of electricity was estimated in two separate forecasts. A direct estimate was made on the basis of the current trends in the industry plus various forecasts that have been made by the provinces; and a supply-demand study of the various competitive energy sources was conducted. A description of this supply-demand study is given in the main report.

Availability

After having analyzed the various conversions, estimates can be made of the total primary energy which must be made available to satisfy Canadian demand. (To convert the total to the primary demand forecast hydroelectricity must be multiplied by a factor 2.93 to change the conversion factor to 10,000 Btu per kWh instead of 3,412 Btu per kWh). The primary energy demand forecast is shown in Table 15 at the conclusion of this Chapter.

Energy Requirements Under High-growth and Low-growth Conditions

Population growth and economic growth are probably the most significant variables in any estimate of Canada's energy requirements.

Population Growth. The projection which was used as a basis for the standard forecast indicates that the population will reach 34-35 million by the year 2000. Under the assumption of a low fertility rate, this figure could be reduced to approximately 29 million while the assumption of a high fertility rate results in an estimate of 38 million or, with a continuing high rate of immigration, 42 million.

The standard forecast is not based on any overall relationship between energy consumption and population. The growth rate of energy consumption per capita has not been constant in Canada. The increase in this ratio was approximately 1% per year over the decade 1950-1960. In the past decade energy use per capita has increased from 170 million Btu to 250 million Btu which is an increase of approximately 3½-4% per year. The slow growth in energy consumption per capita during the fifties was probably due to the transition from an economy based on coal to more efficient fuel usage based on electricity, oil and natural gas. The trend over the past decade is thus more relevant for forecasting purposes.

The standard forecast indicates that, barring major government policy changes, or changes in the present individual Canadian's "energy ethic", the present rate of growth in energy use per capita is likely to continue for another two decades,

after which a gradual slowdown is expected. Calculating from the estimate of total energy use generated by the standard forecast, energy consumption per capita will reach 580 million Btu by the year 2000 from the 1970 level of 250 million Btu, an increase of 132%.

Economic Growth. The rate of economic growth will have a substantial effect upon future energy demand in Canada. The energy-GNP dollar relationship declined

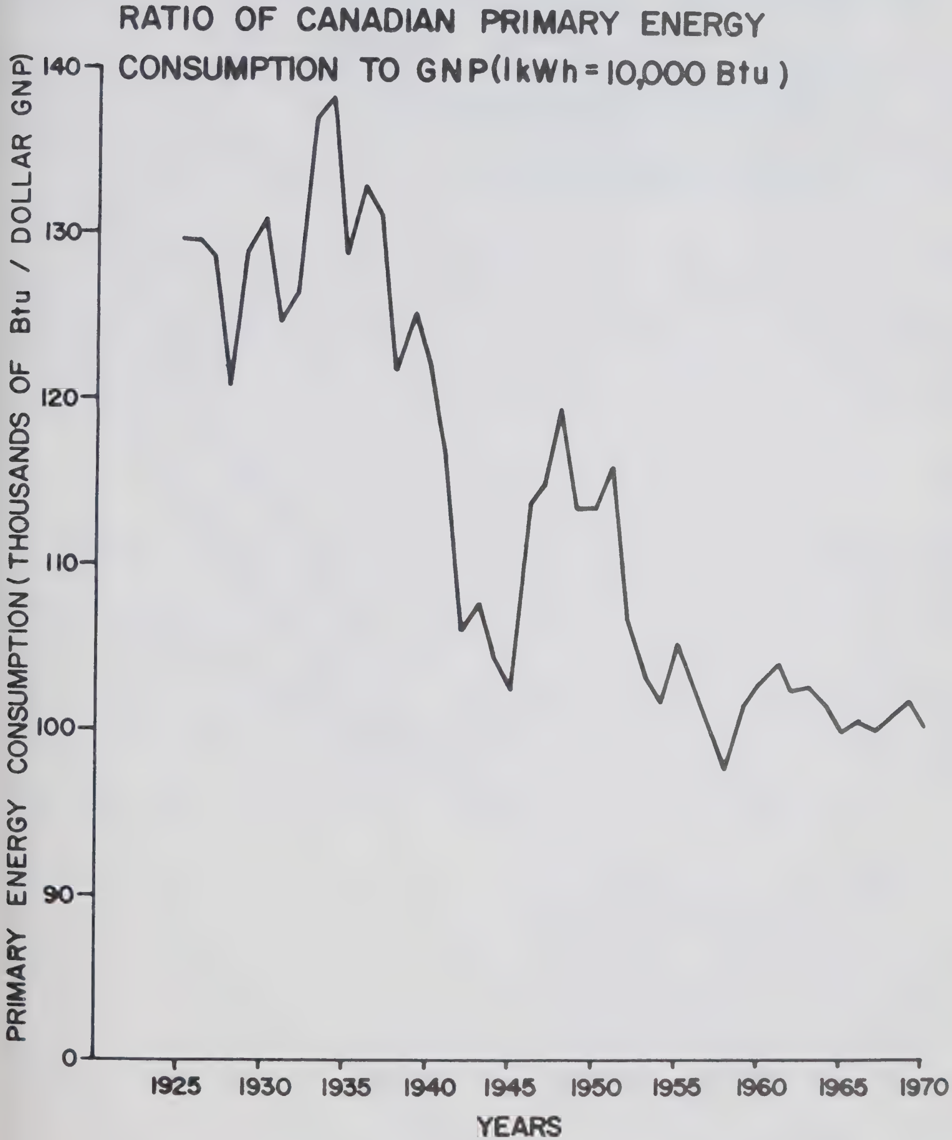

Chart 1

continuously until 1960; since then this relationship has remained relatively constant (Chart 1). In 1970, GNP was $63 billion (1961 dollars) and the primary energy-GNP relationship was 100,000 Btu per dollar GNP. (This is equivalent to a *secondary energy*-GNP ratio of 80,000 Btu per GNP dollar.) If this secondary demand ratio were to remain constant, GNP would reach about $250 billion (1961 dollars) by the year 2000 according to the standard forecast of energy demand (Table 14).

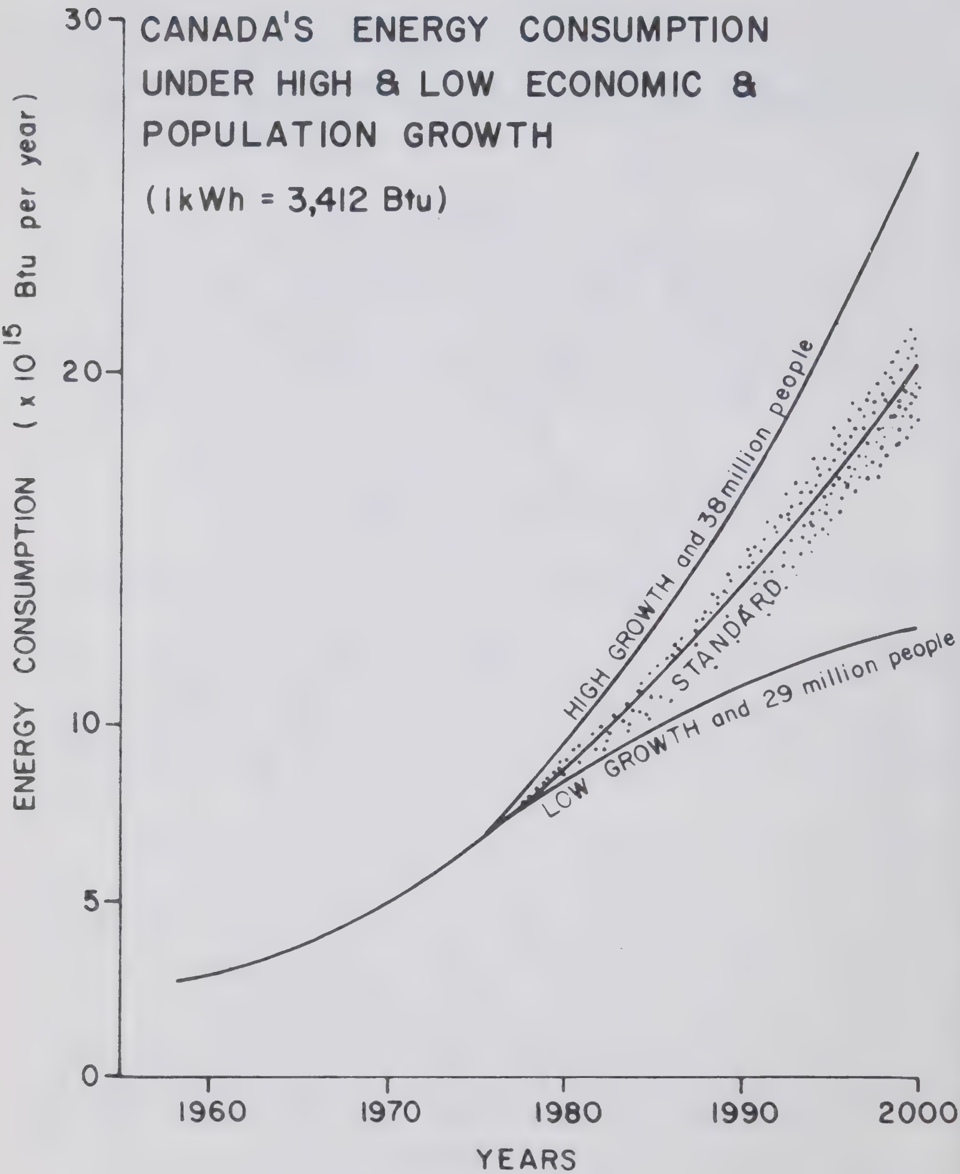

Chart 2

The level of GNP implied by the estimate of total energy consumption changes substantially depending on the choice of the initial year used to extrapolate the energy-GNP relationship. However, for the purpose of this study, it was assumed that this relationship would gradually increase to 90,000 Btu secondary energy demand per dollar GNP. This estimate is based on the assumption that efficiency of energy conversion and use in the future is not likely to increase as rapidly as it has in the past. Using this assumption, GNP could reach a level of about $225 billion (1961 dollars) by the year 2000. To measure the influence of GNP on energy consumption, the energy-GNP relationship was held constant for the various years while *GNP per capita* was varied $\pm$ 5% in 1980, $\pm$ 15% in 1990, $\pm$ 25% in 2000.

The high growth assumption for population combined with the high GNP per capita result in the high growth variation in the demand forecast, while low population growth combined with low GNP growth lead to the low growth variation. The high growth variation results in a secondary energy consumption by the year 2000 of about 26×10^{15} Btu and the low growth variation of about 12×10^{15} Btu (Chart 2).

The relationship of GNP and population to energy consumption is so uncertain that it is rather difficult to forecast energy demand satisfactorily on the basis of these two factors. However, the high growth and low growth variations are introduced to illustrate the magnitude of possible range in total energy consumption resulting from changes in the assumptions regarding the relationship among these macro variables.

Variations in Canada's Energy Requirements

An attempt was made to adequately reflect the uncertainty concerning the long-term pattern of energy consumption in Canada. There are a large number of parameters other than the rate of economic growth and the rate of population growth which will influence the sector forecasts. Energy use will vary within rather wide limits as a result of changes in the structure of society, changes in the direction of government policies including environmental and conservation policies, and changes in the development of technology. A range of estimates was prepared to reflect possible variations in energy demand, by sector, due to alternate assumptions about Canadian society in the year 2000. These estimates are summarized in Table 13.

The Residential Sector. Residential fuel use was estimated to be 1316 trillion Btu by the year 2000 in the standard forecast. However, the degree of possible variation around this figure is considerable. It is probable that total fuel demand will be influenced significantly by the ratio of apartment units to single dwelling units. Consumption of fuels for heating purposes in apartment buildings is considerably less than that of single dwelling units. It is estimated that the ratio of apartment-dwelling households to total households will increase from 29% in 1966 to approximately 33% in 1975. The assumption in the standard forecast was for a ratio of 40% in the year 2000. If this percentage reaches 45% by the year 2000, the estimated total residential fuel consumption will decrease from 1316 trillion Btu to 1260 trillion Btu. If this ratio becomes only 35%, fuel use would be expected

to increase to 1380 trillion Btu. However, the effect of these variations on total energy consumption may be offset to some extent in the future by the trend toward the inclusion of energy-intensive facilities such as swimming pools and saunas in high-rise apartment buildings.

Energy use in the residential sector could be reduced by a number of factors other than the trend toward apartment living. Improvements in the insulation of homes and apartment buildings could result in a sizeable reduction of energy requirements for heating purposes. If the current insulation standards for non-electrically heated homes were upgraded to the standard required for electrical heating as recommended by the Canadian Code for Residential Construction, heat loss and hence energy use for space heating purposes could be reduced by upwards of 30% per home. Applied to new home construction only, this would result in a reduction in residential demand of about 100 trillion Btu in the year 2000. If insulation could also be improved in older homes and apartment buildings it would result in a further reduction of fuel use in this sector of 76 trillion Btu, reducing the overall forecast for the year 2000 from 1316 to 1140 trillion Btu.

The development of a commercially attractive fuel cell for home heating purposes could result in a substantial improvement of the efficiency of fuel use in the home-heating sector. If this fuel cell were able to penetrate the market rapidly enough to be in use in 25% of all single dwelling units by the year 2000, residential fuel demand could be expected to drop from 1316 to about 1230 trillion Btu.

The electricity demand of the residential sector, exclusive of space heating, could range between rather wide limits. As average income rises in the future, new energy-intensive facilities such as electric waste disposal units, electrically heated driveways and electrically heated swimming pools may be featured in homes. Alternatively, the increase in the use of electrical appliances may be less than projected in the standard forecast and greater efficiencies may be developed in the use of appliances. Analysis of these factors resulted in an estimate of the outer limits for electricity demand in the residential sector (other than for heating) of 650-900 trillion Btu.

The Commercial Sector. As mentioned in the description of the standard forecast, the data available on energy consumption in the commercial sector are unreliable. The resulting uncertainty in the projection is so large that no detailed analysis has been made of possible variations in demand due to government policy or technological change. This estimate could vary by ± 1000 trillion Btu by the year 2000.

The Industrial Sector. Variations in the total energy consumption of the industrial sector have been developed in terms of its four most important sub-sectors: the pulp and paper industry, the iron and steel industry, the chemical industry, and the metal-smelting and refining industry.

Variations in the forecast of energy use in the pulp and paper industry are based on two factors: the ability of Canadian firms to compete in export markets and the development of structural processes which could lead to higher efficiency in the use of energy or to different patterns of energy consumption.

Variations in the forecast of energy consumption in the iron and steel industry are based on a growth rate which ranges between 3-3½% per year.

Variations in the forecast of energy demand in the chemical industry are based on the projection of their share of the domestic market. Electricity use in this industry is particularly sensitive to alternate assumptions.

Variations in the forecast of energy use in the smelting and refining industry are based on various assumptions about further processing. Total energy consumption in this sub-sector could vary by a factor of 2 by the year 2000. Fuel use by the four major industries in the industrial sector is estimated to vary from 1500-2000 trillion Btu while electricity consumption will range between 500-1000 trillion Btu. The large variation in electricity demand stems mainly from uncertainty with regard to developments in the chemical industry. Total energy use in the industrial sector could range from 3300 to 5100 trillion Btu.

The Transport Sector. Possible variations in the total energy demand of the transport sector are studied in relation to two sub-sectors: gasoline consumption in automobile transport and fuel consumption in air transport.

In the standard forecast, total gasoline use by automobiles was estimated on the basis of a per capita car ownership ratio of 0.47 and a gasoline consumption per car of 700 gallons by the year 2000. Calculations on the basis of these figures, after including gasoline sales to categories of cars other than those for private use, resulted in an estimate of 2420 trillion Btu.

The demand for gasoline is rather sensitive to variations in two basic parameters: the per capita car ownership ratio and gasoline consumption per car. If we assume a high per capita car ratio, for instance, close to 0.55 and a high gasoline consumption of about 800 gallons per car in the year 2000, and if we also include a somewhat higher gasoline use for non-private cars, then the total gasoline consumption could be approximately 3,000 trillion Btu's. If on the other hand, the per capita car ratio were only 0.4 and the gasoline consumption about 500 gallons per car, then we could have a consumption as low as 1500 trillion Btu's.

In Canada, average fuel consumption per car increased from 589 gallons in 1963 to 643 gallons in 1969. This rather substantial increase probably reflects longer driving distances and the trend toward more powerful cars. If this trend continues in the future, then average gasoline consumption will be considerably higher than the 700-gallon estimate.

A number of other factors could influence the estimate of gasoline use. Regulations designed to control pollution are expected to result in an increase in fuel consumption of 10-20%. Gasoline consumption is directly related to the average size of car. If the average Canadian car decreases in size to the upper end of the small car range, gasoline consumption would be reduced by 14%.

Innovations in automobile technology must also be considered. The development of an economically viable car powered by steam, natural gas, electricity, or a fuel cell, would have a considerable impact on the amount and type of energy consumed by the transport sector.

A rather large range of gasoline consumption is possible in the future because of uncertainty about the transport preferences of the Canadian population, uncertainty about the direction of government policy in the area of transport and uncertainty about the development of technology within the automobile industry, but it is unlikely that the actual consumption will be outside the range from 1500 trillion Btu to 3000 trillion Btu by the year 2000.

Aviation fuel requirements are estimated to range between 800-1200 trillion Btu. The low figure is based on a gradual slowdown of the current growth in air transport.

Considerable variation is possible in the estimates for the other sub-sectors of the transport market. However, in the analysis of the transport sector as a whole, it is likely that these variations will offset each other to some extent.

If the various trends are aggregated, then it is likely that energy consumption in the total transport market could vary in the year 2000 from about 3500-5000 trillion Btu. It is clear from Table 12 that even if it were possible to double all travel by intercity and urban buses and other forms of urban public transport, automobile transport would be reduced by less than 4% of the total. Therefore, it seems unlikely that more than 10% of automobile transport capacity can be shifted to the other sectors.

TABLE 12

PASSENGER MILES IN CANADA IN 1967 FOR VARIOUS FORMS OF TRANSPORT

Automobiles	87.7%
Airplanes	5.6%
Trains	3.2%
Intercity and rural buses	2.3%
Urban buses	0.8%
Other urban public transit	0.4%

Non-Energy Use. No variations were studied for this market.

Energy Industries. Consumption by the energy industries depends heavily on the total energy requirements of the economy. If total consumption of energy were to be considerably less than that predicted by the standard forecast and no important exports of oil, gas, coal or electricity were to take place in the year 2000, then consumption by the energy industries would be considerably less than estimated in the standard forecast; 2200 rather than 3900 trillion Btu. If energy consumption were to be higher and substantial exports were to occur, use by energy industries would be higher, possibly as much as 4700 trillion Btu.

TABLE 13

VARIATION ON BASIS OF STANDARD FORECAST IN YEAR 2000
(*trillion Btu's*)

Sectors	Minimum	Standard	Maximum
Residential	1,800	2,099	2,300
Commercial	3,500	4,485	5,500
Industrial	3,300	4,195	5,000
Transport	3,500	4,471	5,000
Non-energy	800	821	900
Energy industries	2,200	4,157	4,700
Total	15,100	20,228	23,400

Table 14

SUMMARY OF 'STANDARD' FORECAST OF CANADA'S SECONDARY ENERGY CONSUMPTION

(10^{15} Btu)

	1970	%	1980	1990	2000	%
Petroleum products	2.9	58	4.6–5.1	6.0–9.4	8.2–13.5	79
Natural gas	1.1	22	2.5–2.0	5.4–2.0	7.7–2.4	
Coal, coke[1]	0.3	6	0.3	0.3	0.4	2
Electricity	0.7	14	1.4	2.4	3.9	19
Total	5.0	100	8.8	14.2	20.2	100

Note: Figures may not add up to totals due to rounding.
[1]Includes petroleum coke.

Table 15

'STANDARD' FORECAST OF CANADA'S PRIMARY ENERGY CONSUMPTION

(10^{15} Btu)

	1970	%	1980	1990	2000	%
Petroleum	3.1	48	4.8–5.4	6.7–10.2	9.4–14.6	63
Natural gas	1.2	18	3.1–2.5	6.0–2.5	8.2–3.0	
Coal	0.7	11	1.1	1.6	1.9	7
Hydroelectricity*	1.5	23	2.3	3.1	3.4	12
Nuclear and other	—	—	0.5	2.0	5.1	18
Total	6.5	100	11.9	19.4	28.0	100

Note: Figures may not add up to totals due to rounding.
*Hydroelectricity at 10,000 Btu per kWh.

(Natural Units)

	1970	1980	1990	2000
Petroleum (MM bbls/day)	1.5	2.3–2.5	3.2–4.8	4.4–6.9
Natural gas (billions of Mcf)	1.2	3.1–2.5	6.0–2.5	8.2–3.0
Coal (millions of tons)	26	49	84	100
Hydroelectricity (billions of kWh)	156	235	310	344
Nuclear (billions of kWh)	—	45	180	502

Conclusions

In this section, variations have been studied in the pattern of energy use within the various sectors. The combination of all the low estimates and all the high estimates results in an estimate of the outer limits of the demand for energy. This is a rather hypothetical exercise because it is very unlikely that all the low estimates or all the high estimates will occur simultaneously. Within the

industrial sector, for example, a lower estimate for one industry is likely to be offset by higher projections for other industrial activities mainly because capital and labour resources will be used in a somewhat different pattern from that assumed in the standard forecast. It is also possible that a lower estimate for the residential sector will result in a higher figure for the commercial sector. For example, a significant expansion of launderettes could be offset by a reduction in the use of washing machines in the residential sector.

Therefore, it is unlikely that all the high estimates or all the low estimates would occur simultaneously in the absence of major government intervention. However, the aggregation of the figures results in a general insight into the possible outer limits of energy consumption. As can be seen in Table 13, total energy consumption could range from 15,100-23,400 trillion Btu or from approximately 25% less than the figure in the standard forecast to 15% more than the standard forecast. These variations do *not* reflect changes in population or economic growth projections.

It is of interest to study the extent to which possible government action could reduce energy consumption in view of the present extensive discussions about this subject. If the standard forecast is taken as a point of departure, it would appear that one of the more obvious areas of possible government influence would be in regulations with regard to the transport sector and, to a minor degree, regulations with regard to the residential sector. Active government policies could reduce demand in these areas by approximately 5% of the total energy demand suggested by the standard forecast in the year 2000. Less defined possibilities for higher efficiency use of energy probably exist in the commercial and industrial sectors. Also, increases in efficiency are possible during the conversion of energy, and it is possible to recover more of the conversion losses. Higher efficiencies of equipment at the final consumer end could also contribute to an ultimate reduction of energy use. As indicated by Table 13, major government involvement in all areas, accompanied by changes in the aspirations of individual Canadians and some technological improvements could bring about a reduction of the standard forecast of approximately 25% by the year 2000.

The above-noted reductions of energy consumption do not include the possible effects of a slowdown in the general rate of economic growth or in the rate of population growth. If the effects of variations in economic growth, variations in population growth, and variations based on structural changes as discussed in this last Chapter are aggregated, then it appears that total energy consumption in the year 2000 could be substantially different from that projected in the standard forecast. It is difficult to assess the various combinations, but it appears that the outer limits of energy consumption could range from 35% higher to 45% lower than the standard forecast.

Chapter 2

ENERGY RESERVES AND POTENTIAL RESOURCES (A) OIL AND GAS

This paper is concerned with the quantities of oil and gas within the sedimentary basins of Canada which, if discovered, will be available for exploitation. Economic constraints related to these estimates are discussed in another section of the report. Definition of the various terms relating to resources (reserves and potential) follow this introduction.

The total resources may consist of proven reserves and undiscovered (potential) oil and gas and the proportion between the two will vary widely depending upon the degree of exploration within a given region. Resource figures for Canada are summarized on Table 1. The figures reported for proved reserves of oil and gas, and those for oil sands and heavy oils (items 1, 2, 5 and 6 on Table 1) are quoted from various sources. Estimates of potential oil and gas have been prepared by the Geological Survey of Canada and are discussed in detail in this report. The conventional oil and gas potential for Canada is evaluated on a probability basis, and is derived from careful consideration of the geology, geochemistry, geophysics and proved reserves of each sedimentary basin, both on and offshore. The estimates are compared with other estimates made during the last four years. Estimates of potential oil and gas resources will change as continued exploration and development yield additional data leading to improved interpretations.

Most of the petroliferous sedimentary basins of Canada contain oil which is recoverable by conventional technologies. Large resources exist, however, particularly in Alberta, in the form of oil sands. The total oil in place is relatively well known, but there is still the need to develop adequate technology for its economic recovery. Therefore, assessment of the volume of recoverable oil is a matter of great difficulty, except for the relatively limited quantities available to open-pit mining methods.

DEFINITIONS

The terms used in this appendix are defined as follows:

1. *Conventional oil*—that which is recoverable from a well bore by conventional technologies.

2. *Non-conventional oil*—a viscous oil incapable of being produced by conventional technologies from a well bore. It includes, particularly, oil from the various oil sands which is or may be recovered by mining or thermal techniques.

TABLE 1

CANADA'S OIL AND GAS RESOURCES

	In Place	Recoverable	Cumulative Production	Remaining
1. Proved Oil Reserves (Conventional)[1,2] Billion Bbls.				
NWT	0.5	0.1	<0.1	<0.1
W. Canada	43.8	15.9	6.2	9.7
E. Canada	0.2	0.1	<0.1	<0.1
Subtotal	44.5	16.0	6.3	9.7
2. Proved Natural Gas Reserves[2,3] Trillion Cu. Ft.				
NWT	2.0	1.3	—	1.3
W. Canada	116.5	69.1	17.8	51.4
E. Canada	1.1	1.0	0.7	0.3
Subtotal	119.6	71.5	18.5	52.9
3. Potential Oil (Conventional) Billion Bbls.		4 5		4 5
Arctic Islands & NWT		70.1—28.1	—	70.1—28.1
W. Canada (Provinces)		6.5— 4.6	—	6.5— 4.6
East coast		41.7—50.4	—	41.7—50.4
Subtotal		118.3—83.1		118.3—83.1
4. Potential Natural Gas, Trillion Cu. Feet		4 5		4 5
Arctic Islands & NWT		481.1—341.7	—	481.1—341.7
W. Canada (Provinces)		100.5— 43.7	—	100.5— 43.7
East coast		253.1—326.1	—	253.1—326.1
Subtotal		834.7—711.5	—	834.7—711.5
5 Alberta Oil Sands[6] Billion Bbls.				
Open-Pit Mineable		65.0	0.1	64.9
"In-Situ" Recovery		235.9		235.9
Subtotal	710.8	300.9	0.1	300.8
6. Alberta Heavy Oil[7] Billion Bbls.	75.0	30.0	—	30.0
7. Total Resource (BOE) Billion Bbls.	—	616.2—560.5	9.5	606.7—551.0

NOTE: Totals may not add due to rounding.

FOOTNOTES TO TABLE 1:

[1]Includes natural gas liquids.

[2]Source: Canadian Petroleum Association (December 1972).

[3]Figures quoted for "In Place" gas are on a raw gas basis, all others are pipeline gas.

[4]Geological Survey of Canada (February 1972) estimates of ultimate recoverable potential less proved reserves.

[5]Geological Survey of Canada (March 1973) estimates of ultimate recoverable potential less proved reserves.

[6]Source: Oil and Gas Conservation Board, "A Description and Reserve Estimate of The Oil Sands of Alberta", October 1963.

[7]Source: "The Oil Sands of Alberta"—H. J. Webber, The Journal of Canadian Petroleum Technology, October-December 1967.

3. *Proved reserves of oil and gas*—that which can be demonstrated with geological and engineering data to be recoverable with reasonable certainty under existing economic and operating conditions.

4. *Original in place reserves*—the oil or gas initially in place within a pool, part of which is recoverable, and another part non-recoverable.

5. *Recoverable potential* (resources)—the quantities of oil and gas postulated to be present in sedimentary rocks and that are potentially available through intensive exploration.

6. *Ultimate recoverable potential*—the proved reserves (both produced and remaining) added to the recoverable potential.

7. *Natural gas liquids* (N.G.L.)—are the low molecular weight hydrocarbons coproduced with natural gas: propane, butanes, and pentanes plus.

8. *BOE* (*barrels of oil equivalent*)—oil in barrels plus oil equivalent of gas converted on a thermal basis (6,000 cubic feet equivalent to one barrel) together expressed in barrels.

ESTIMATES OF CANADA'S OIL AND GAS RESOURCES

Canada's oil and gas resources consist of both proven reserves and undiscovered potential. Estimates of the reserves in a variety of categories are made and published periodically by various provincial and federal government agencies and the Canadian Petroleum Association. Parts of the most recent CPA compilation, giving reserves as of December 31, 1972, are included in Table 1. This table also includes estimates of nonconventional oil reserves, such as the Athabasca Oil Sands and other Alberta heavy oil deposits that cannot be produced by conventional oil technology.

Estimates of undiscovered potential have been prepared by the Canadian Petroleum Association, the Canadian Society of Petroleum Geologists, and the Geological Survey of Canada. The most recent evaluation by the Geological Survey of Canada is presented in this paper in some detail for the first time.

The Geological Survey of Canada (1973) Evaluation of Canada's Ultimate Recoverable Potential

The problem of evaluating the petroleum potential of large regions is extremely complex. Estimates as to the total resources of the world vary by at least an order of magnitude. Within countries with a petroleum potential, estimates vary almost as widely. When individual petroleum-bearing basins are considered, however, the spread in estimates will depend on the degree of development that already has taken place, and on the magnitude of proven and probable reserves, if any. Thus, in Canada, basins containing a high proportion of proved reserves, such as the Prairie Provinces, will have a relatively narrow spread of probable potential. In other basins, such as Baffin Bay or Labrador Shelf, not one cubic inch of rock has yet been examined nor a drop of oil discovered and, consequently, the estimates will embody a high degree of uncertainty, which may be expressed as a broad probability curve.

The technique of evaluation depends on constructing cumulative probability curves for oil, gas, and barrels of oil equivalent for each basin or sub-basin (Figure 1). These curves are drawn according to the best judgement in relation to known petroleum occurrences and reserves, probable petroleum "plays", volume of sediments in basins, and a yield factor per unit volume based on basin classification in relation to other regions of the earth's crust. Because the curves are necessarily asymmetrical (skewed), the mean is computed to allow comparison between areas and to permit summing in order to arrive at a regional or country-wide mean total. This mean may not be taken as a unique reliable potential estimate. The shape of the probability curve will give the best indication of the possible spread in values and a measure of their relative probabilities. The means of the probability curves for oil, gas, and barrels of oil equivalent are summarized on Table 2. The curves for all basins have been summed and a final overall curve derived to express the potential for all of Canada, again on a probability basis (Figure 3).

Method

Canada's potential petroleum resources have been estimated using a system in which all geologically conceivable "exploration plays" or groups of "plays" in a given basin are considered in a probability framework and rationalized with estimates derived from "volumetric" analysis. The first phase of this process consisted of identification of the exploration "plays" present in each basin. Each "play" represents a specific geological configuration of source rock, reservoir, trapping mechanism, and preservation which is considered prospective for hydrocarbons. For each "play" there are possibilities of the occurrence of both oil and gas systems, separately or together. Identification of the "plays" and associated oil and gas systems relied heavily on an established basin analysis program to provide:

Recognition of basic geological sequences within a basin,

Appreciation of the basic facies relationships within each sequence,

Definition of the structural history of the basin,

CANADA'S PETROLEUM BASINS

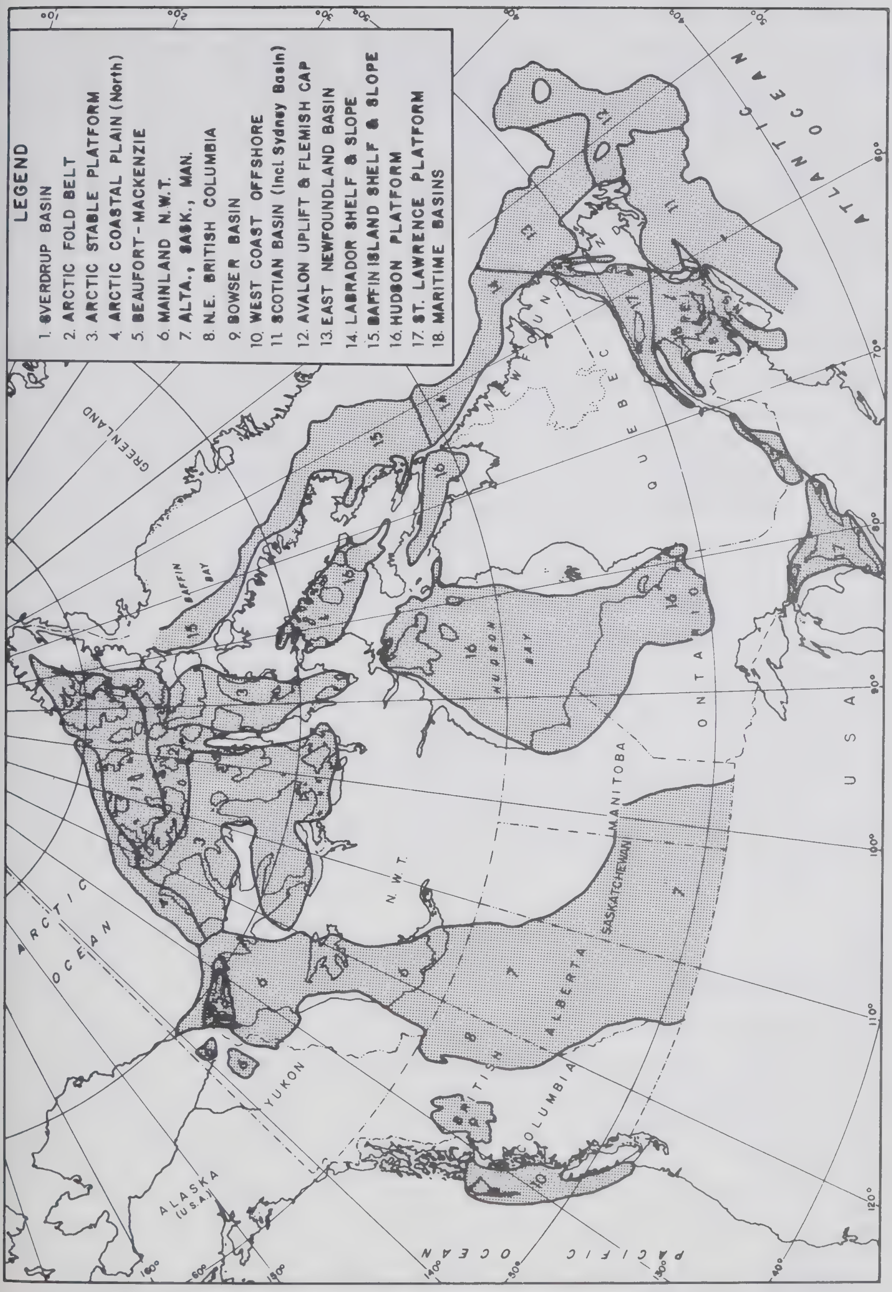

Figure 1

TABLE 2

CANADA'S ULTIMATE RECOVERABLE POTENTIAL

(based upon GSC 1973, evaluation)

Basin	Ultimate Recoverable Oil (B.bbls.)*	Ultimate Recoverable Gas (Tcf)*	Ultimate Recoverable BOE (B.bbls.)*
1. Sverdrup Basin			
Land	7.2	118.8	27.00
Offshore	4.7	79.2	17.92
2. Arctic Fold Belt			
Land	2.6	15.2	5.09
Offshore	1.1	6.8	2.20
3. Arctic Stable Platform			
Land	0.6	0.6	0.69
Offshore	0.6	0.6	0.69
4. Arctic Coastal Plain (North)	3.5	20.8	6.84
5. Beaufort-Mackenzie			
Land	3.5	50.0	11.83
Offshore	2.7	43.5	9.95
6. Mainland N.W.T.†	1.7	7.5	2.96
7. Alberta, Saskatchewan, Manitoba†	18.3	82.2	31.97
8. N.E. British Columbia†	1.6	21.4	5.10
9. Bowser Basin	—	5.6	0.93
10. West Coast Offshore	0.6	3.6	1.20
11. Scotia Basin (including Sydney Basin)			
Shelf	3.7	28.0	8.41
Slope	5.5	42.1	12.62
12. Avalon Uplift & Flemish Cap			
Shelf	0.3	1.9	0.66
Slope	2.3	12.9	4.41
13. East Newfoundland Basin			
Shelf	10.2	60.9	20.37
Slope	5.3	31.3	10.50
14. Labrador Shelf & Slope	5.5	38.7	11.96
15. Baffin Island Shelf & Slope	14.7	91.3	29.92
16. Hudson Platform	1.5	7.3	2.72
17. St. Lawrence Platform†	0.6	3.6	1.22
18. Maritime Basins†	0.9	9.1	2.47
Totals:	99.2	782.9	229.63

* Values given are calculated means of individual curves.
† Includes proven reserves (both produced and remaining).

Appreciation of all geochemical and other oil occurrence indicators that were available,

Appreciation of the degree of definition which could be placed on the various geological configurations under consideration.

In the next phase, estimates were made of the amount of oil and/or gas that might be present in each exploration "play". Ideally, the potential of each play should be expressed in the form of a continuous probability distribution curve, where the probability of occurrence is plotted against the potential (see Figure 2). The probability curves for each play would then be summed to produce a composite curve for each basin. In the present study, although as many plays as could be conceived were considered, only the composite curves were drawn because most of the basins are insufficiently explored to expect more meaningful results from combining individual curves. The curve for each basin therefore reflects the probabilities associated with the whole spectrum of "plays" that were considered.

In practice, preparation of the probability curve for each basin began with a review of the geology of each play. The potential estimates committee then attempted to define as many points on a basin curve as possible, by consensus of the informed geologists. In each case the points reflected an answer to the question, "What is the probability that potential equal to or greater than 'X' exists?"

The type of judgement required for an evaluation exercise of this nature is derived from a broad knowledge of the geoscience base of each basin. Such a base is the result of field and laboratory studies within the disciplines of geology, geophysics, and geochemistry. All available data are used to contribute to the knowledge of the geoscience base of each basin in Canada. Many of these data come from confidential sources including information derived from drilling and geophysical surveys by petroleum companies. In some areas the known reserves are equally confidential. All data are thus unified by a synthesis, analyzing the geological history, three-dimensional geometry, structure and geochemical and sedimentary characteristics of each basin from which are derived opinions as to systems of petroleum occurrence. These opinions are then expressed in the form of a continuous probability curve (Figure 2).

Curve A represents a basin in which significant discoveries already have been made (proven reserves are 3 billion barrels) and the factors which control the occurrence are well known. There is 90% probability of there being more than 7 billion barrels present, 50% of more than 10 billion barrels, and only 5% probability that the total will exceed 15 billion barrels. The curve in example B shows a typical high-risk basin with high potential. There is only a 50% chance of significantly greater than zero potential, but if oil is found a quantity ranging up to 30 billion barrels may be present.

Initial Point of Curve

In basins in which proven reserves already have been established, those reserves are entered at 100% probability (see Curve A, Figure 2). The curve for this type of basin begins as a horizontal line and then becomes convex upwards. For a basin in which there has been sufficient drilling to establish the presence

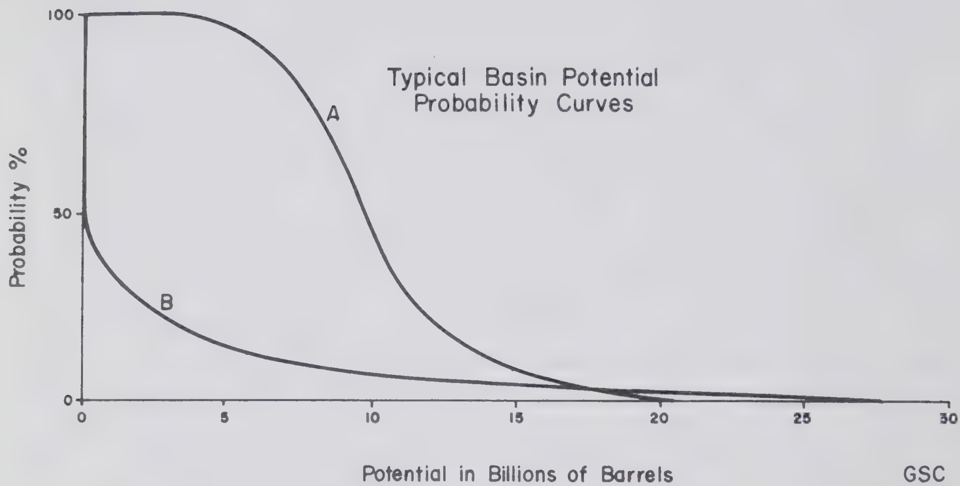
Typical Basin Potential
Probability Curves
A
B
100
50
0
Probability %
0
5
10
15
20
25
30
Potential in Billions of Barrels
GSC

Figure 2

of hydrocarbons and possible reservoirs and traps, but lacking significant discoveries and proven reserves, the curve is drawn through zero potential at 100% probability, declining with slight upward concavity. Unexplored and poorly understood basins in which geological plays can be identified are described by a curve similar in configuration but declining very abruptly from the 100% value (Curve B). Significant departure from the vertical axis might not occur until the 50% probability of occurrence level is reached. (Note that each of these curves represents a cumulative continuous probability function and as such must originate at the 100% cumulative probability level.) For such an unknown region, the hydrocarbon potential would only be significantly greater than zero at the 100% level if and when the critical factors of source beds, reservoirs, trapping and preservation were eventually found to be favourable. The choice of level of significant departure from zero potential is based on geological judgement of the extent to which the critical factors are likely to be favourable, and as such, reflects the degree to which an adequate geoscience base is available and understood.

End Point of Curve

The maximum potential assigned for each basin, always expressed at minimal probability, is selected by consensus of geological judgement, usually based on direct comparison of projected ultimate potential of analagous plays and basins. In early stages of exploration this end of the curve or "tail" generally tends to be optimistic in that it allows for the most fortuitous combination of critical factors for the type of basin being considered, even if at a very low probability. As the geology of a basin becomes better known, and the limiting factors better understood, the length of the tail and the maximum potential can be more confidently selected.

Intermediate Points and Shape of Curve

Intermediate points on the basin curves at probabilities of 25, 50, and 75% are more difficult to establish than those at zero and 100% because these parts of the curve are actually a composite of curves for several plays. However, in most basins one or two plays are dominant and tend to determine the general shape of the composite curve. As indicated in Figure 2, the shape of the curve is a measure of how much is known about a play or basin. Curves for plays or basins which are well explored and have proven reserves are flat at the top, have rather steep intermediate sections and short tails as limiting factors are reasonably well understood. Curves for poorly known plays tend to decline abruptly from the 100% probability level, are concave upwards, and have long tails. The composite curve for a basin commonly combines plays that are well explored, perhaps with proven reserves, with plays which at present are entirely hypothetical, perhaps at great depth or offshore. The combination of several plays generates a complex curve which must be smoothed for the present exercise.

Volumetric Method

The volumetric method of potential estimation was used as a test of the overall judgement expressed in the curves, and as a check on mid-point and maximum

values. The volumetric method consists of multiplying the volume of sedimentary rocks in a basin by a yield factor (barrels of oil per cubic mile) considered appropriate for the type of basin under consideration. Yield factors are derived from geologically analagous basins where ultimate recoverable potential and volume have already been determined. "Volumetric" estimates reflect the broad expectations of the potential of a basin without reference to specific plays.

In the present exercise the mean of the probability curves was compared to the potential derived by the volumetric method. If the two values were significantly different, then the assumptions supporting the two values were reconsidered.

The geoscientific data base from which estimates have been derived is very large, highly technical, and in large part held in confidential status. Because of this, individual probability curves, and details of geology, geophysics, or geochemistry related to specific basins cannot be discussed in this report. Summary comments on the geology of each basin are presented below, however, to indicate general characteristics that contribute to their relative hydrocarbon potential.

Pool Size Distribution

The sizes of oil and gas pools that would be anticipated with each play in a basin were considered during the preparation of the basin curves. For each play, a log normal distribution can be assumed, and if the largest pool size for each play is determined, then an array of pool sizes for each basin can be postulated.

Figure 3 is a cumulative probability curve for total barrels of oil equivalent for all of Canada. It results from summing the curves for each basin as discussed above. The mean values for all of Canada are 99.2 billion barrels of oil, 782.9 trillion cubic feet of gas, and 229.6 billions of barrels of oil equivalent (BOE). The curve on Figure 3 expresses a range of probabilities in a cumulative manner. Thus, according to present knowledge and judgement, there is an 80 per cent chance that the Ultimate Recoverable Potential of the country is more than 184 billion barrels, but there is only a 20 per cent chance that the figure will exceed 272 billion barrels. The horizontal portion of the curve at 100 per cent probability represents proven reserves and the virtual certainty that there will be more oil discovered than this. Values for the probability associated with any potential estimate may be quickly determined from the curve.

Discussion of Geology

Arctic Islands

Synopsis of geologic history. The geological history of the Arctic Islands may be divided into two major time intervals: Cambrian to Late Devonian (Franklinian Geosyncline) and Carboniferous to Tertiary (Sverdrup Basin). From Ordovician to Early Devonian time, geosynclinal sedimentation was characterized by trough deposition from northern Ellesmere to northwestern Melville Island, with contemporaneous shelf deposition to the west of the trough in northwestern Ellesmere, and to the east and south of the trough in the areas of the present Arctic Fold

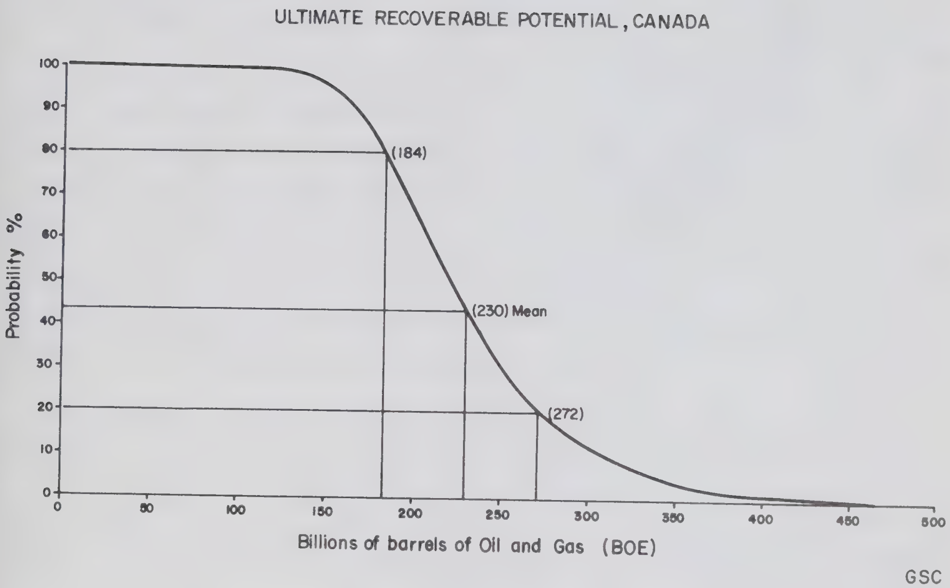
ULTIMATE RECOVERABLE POTENTIAL, CANADA
Probability %
100
90
80
70
60
50
40
30
20
10
0
(184)
(230) Mean
(272)
0
50
100
150
200
250
300
350
400
450
500
Billions of barrels of Oil and Gas (BOE)
GSC

Figure 3

Belt and Stable Platform. In the southern and eastern areas, evaporites are present throughout the section with major thicknesses of halite and anhydrite in the Lower Ordovician. Extensive reefoid carbonate accumulations formed on the southern and eastern shelves during Ordovician, Silurian and Devonian time. By Late Devonian time, with the onset of Ellesmerian uplift to the north, synorogenic clastic wedges spread southward across the trough and shelf. Ellesmerian uplift and folding continued into Mississippian time and terminated deposition in the Franklinian Geosyncline.

Following an extended period of erosion, the Sverdrup successor basin developed along the axis of the earlier Franklinian geosynclinal trough.

During parts of Mesozoic time, at least, there were relatively positive areas along the northwestern margin of the basin. However, at other times during the Mesozoic and late Paleozoic the basin may have been open to the northwest. Along the eastern and southern margins the present outcrop distribution approximates the depositional edge of the basin.

Initial Pennsylvanian sedimentation produced widespread basal red-bed deposits and basin centre evaporites, followed by Pennsylvanian basinal shales, as well as shelf and reefoid carbonates. Late Permian deposition of basinal shales and cherts and marginal sandstones was followed by pre-Mesozoic regional erosion.

Terrigenous clastic deposition occurred throughout the Mesozoic and resulted in a general division of the section into marginal sandstone and basinal shale provinces. Major cycles of transgression and regression, with some major periods of widespread erosion within the basin, resulted in six major ingressions of deltaic systems. The sandstones within these systems provide the reservoirs for Mesozoic pooled hydrocarbons.

In early Tertiary time the basin filled with nonmarine sediments; deposition in the Sverdrup Basin was terminated by mid-Tertiary Eurekan uplift and folding, with associated deposition of synorogenic nonmarine units.

Diapirs of Pennsylvanian evaporites are common in the Sverdrup Basin. Some of the diapirs rose during the Eurekan Orogeny but some may have been active as early as Jurassic time.

1. *Sverdrup Basin*. Conditions appear to have been favourable for generation and migration of hydrocarbons in the Mesozoic sequence of sandstone and shale. Shales are common and are associated closely with reservoir rocks. Geochemical studies indicate that the shales are adequate source rocks, and that depth of burial, for the most part, has been sufficient for generation and migration of hydrocarbons. The sandstones are commonly good reservoirs.

A favourable factor, in terms of traps, is the nature of the geometry of the Triassic and Jurassic sandstone bodies. These units form lobate sandstone extensions into the shale basin and, in the Upper Triassic, sandstones extend across the basin to form up-dip pinchouts along the northwestern side of the basin, a configuration that could result in major stratigraphic traps. Migration from stratigraphic traps into later-formed structural traps may have occurred and may explain why some structures, which are miles long and have thousands of feet of closure, are only partially filled by hydrocarbons.

Major unfavourable factors in consideration of hydrocarbon potential are: the apparent late formation of structure; the breaching of reservoirs by erosion; the possible loss of pooled hydrocarbon due to late structural dislocation; and, in terms of oil, the possibility of increased geothermal gradient related to major igneous intrusive activity in the northeastern part of the basin. These factors all downgrade the area northeast of Amund Ringnes, about one third of the basin. Generally throughout the basin, the Cretaceous reservoirs are breached, leaving about two thirds of the Mesozoic stratigraphic section prospective over about two thirds of the basin.

Although diapirs of Pennsylvanian evaporites are common, many resulted from Tertiary structural movements and, as such, are not favourable for entrapment of Mesozoic hydrocarbons. Others, particularly those southwest of Axel Heiberg, could have been activated as early as Jurassic time.

The Upper Paleozoic portion of the Sverdrup Basin differs from the Mesozoic section in that it contains large amounts of carbonate and evaporite rocks. Adequate source rocks are present but the depth of burial over most of the basin suggests the sequence should be relatively gas prone. Prospective reservoirs are marginal sandstones and various carbonate units, including large reefoid build-ups. The sandstones, though commonly porous, are cut by numerous unconformities and commonly lack top seals. The exposed carbonate build-ups are generally tight but had very high primary porosity. Although the upper Paleozoic rocks were involved in Tertiary structural movements, there is little evidence, as yet, of major pre-Mesozoic structural developments that would have provided early structural traps for upper Paleozoic rocks, but it appears that the upper Paleozoic pools will be small and gassy relative to the Mesozoic accumulations.

Because of the high gas to oil discovery ratio to date, and because much of the prospective section has been buried to more than 10,000 feet, the Sverdrup Basin is considered to have a higher than normal gas-oil ratio.

In summary, the Sverdrup Basin has good hydrocarbon potential and, in fact, much gas and some oil have been found; but the possibilities of occurrence of major accumulations of hydrocarbons in the easily identified, large surface structures must be discounted somewhat. There is, however, much variation in the geology within the basin and a number of different oil and gas systems are anticipated, most of which have not yet been evaluated by drilling. Some giant fields are anticipated in the Mesozoic rocks, but fields in the upper Paleozoic are likely to be smaller. It is to be noted that the yield factor for the basin is considerably higher than the yield factor for Western Canada.

2. *Arctic Fold Belt*. Potential source rock is abundant and in part closely associated with potential hydrocarbon reservoirs. Burial has been great enough to generate hydrocarbons and to cause migration. Potential reservoirs are Devonian sandstones, Devonian-Silurian-Ordovician reefoid carbonates and Ordovician carbonate-evaporite associations.

Large folds formed during the Late Devonian would seem to be later than the primary migration of hydrocarbons into unbreached reservoirs; however, secondary migration into the structures may have occurred. There are areas, like the Boothia uplift, where earlier movements may have produced structural traps

but it appears that the major traps to be expected are stratigraphic in nature. The carbonate reservoirs have the potential of the Devonian carbonate plays of Alberta but possible Devonian sandstone reservoirs appear to be largely breached. Although no significant hydrocarbon accumulations have been found to date, there is a possibility of getting giant fields in the reefoid carbonates.

3. *Arctic Stable Platform.* Potential source rocks are present but not abundant on the Arctic Stable Platform. Potential reservoirs include Devonian sandstone, Devonian-Silurian-Ordovician shelf carbonates and basal Cambrian sandstones. Structural traps may exist at depth, associated with local basement uplifts. In addition, large stratigraphic traps may be present. However, in most of the area, the stratigraphic section is thin and many of the reservoirs are breached. Because of relatively shallow burial most of the area is likely to be oil prone. Pools are likely to be relatively small and in carbonate reservoirs.

4. *Arctic Coastal Plain (North).* Geological information concerning the Arctic Coastal Plain is minimal. It appears that a large proportion of the volume, to explorable depths, is part of a Tertiary deltaic system, and, by analogy, may be similar to parts of the Beaufort-Mackenzie area and highly prospective, although diapiric structures have not yet been identified. The remainder of the volume is composed probably of Mesozoic and upper Paleozoic rocks similar to those along the northwestern margin of the Sverdrup Basin, and is also highly prospective with respect to oil and gas. In view of the lack of knowledge, however, a low probability is associated with estimates of the potential of the area.

Western Canada

5. *Beaufort-Mackenzie Basin.* The Beaufort-Mackenzie Basin is similar to the Gulf Coast and Niger Basins, and consists of a thick succession of Mesozoic and Cenozoic sedimentary rocks developed upon the northern continental margin of North America. The sequence overlies older Paleozoic sedimentary rocks which, within the basin, are deeply buried but which, at its southern margin, are exposed within a complex structural element, the Aklavik Arch. The gross structural setting of the basin combined with the nature of its enclosed rocks makes it a highly favourable petroleum province.

The Mesozoic and Cenozoic sedimentary succession consists of intercalated deltaic and shallow marine sandstones and siltstones which pass northward into open marine shales which constitute favourable petroleum source rocks. On the north flank of the Aklavik Arch, the sequence is dislocated by a series of mainly down-to-basin normal faults which, although active at several times during the Paleozoic era, underwent further movement synchronously with Late Cretaceous and Tertiary deposition. These later movements allowed for the development of a thick succession of deltaic sediments. Seaward from this fault zone the total Mesozoic and Cenozoic sequence reaches a thickness in excess of 30,000 feet. Part of this succession has been deformed into a series of northwesterly trending linear diapiric anticlines. The length and closure of these structures is great and associated features such as growth faults, unconformities and roll-over anticlines add to the petroleum potential, particularly in the offshore area.

The basin can be divided essentially into two main exploration "plays", each including several smaller specific plays. Beneath the Tuktoyaktuk Peninsula, Jurassic and Lower Cretaceous rocks within rotated fault blocks are currently being explored and oil and gas have been discovered within the Lower Cretaceous sandstones. Included with this "play" is the oil discovery within the upper portion of the sub-Mesozoic Devonian carbonates. The reservoir may be related to porosity developed during the long interval of post-Devonian—pre-Cretaceous erosion and/or fracturing imparted to the rocks during the Late Cretaceous-Tertiary period of deformation. The "reefoid" character of these Devonian rocks cannot be overlooked and thus it is possible that reservoirs of Devonian oil may be present in the area.

Pool sizes in this region are likely to be small and limited by the amount of closure within rotated fault blocks. To date the number of successes within these structures is disappointing but many remain to be tested.

The other major play, and by far the larger, is in the Late Cretaceous and Tertiary deltaic succession developed beneath the modern Mackenzie Delta and the adjacent offshore area. A thick succession of nonmarine and marine sediments associated with diapirs and related structures of large magnitude have a high potential. Most of the discoveries in this region have been gas and, as similar successions in other comparable basins are gas prone, a high gas yield is expected from these rocks. Depths of burial and the nonmarine nature of much of the succession also suggest a relatively gas rich basin.

Pool sizes within the Late Cretaceous and Tertiary deltaic succession could be very large, particularly in the offshore area of large diapiric structures. On northern Richards Island, stacked gas reservoirs have been encountered in each successful well. The thickness of the sandstone bodies is variable, and within the deltaic sequence the number of such units could be very great. In the offshore region most exploration initially will probably be devoted towards possible structural traps but numerous possibilities exist for stratigraphic and combination traps related to diapirism.

A supporting factor for the substantial potential in this area lies in the similarity between this basin and the Gulf Coast Basin both structurally and stratigraphically. It is reasonable to expect that the yield factor for the petroleum potential of the Beaufort-Mackenzie Basin will not be unlike the Gulf Coast.

6. *Northwest Territories—Mainland*. Most of this large area lies on the craton. It is bounded on the east by the Precambrian Shield and on the west by the Mackenzie and Richardson Mountains. Within this region sediments range in age from Cambrian to Tertiary. With the exception of Eagle Plains Basin and several other relatively small areas, the upper Paleozoic to Tertiary rocks are too thin, too shallow, are breached or have facies unfavourable for significant petroleum potential. The main hydrocarbon potential is therefore limited to the Upper Cambrian to Middle Devonian succession.

These rocks form a wedge of shallow marine sediments which thickens from zero in the east to several thousand feet adjacent to the mountain front and, over much of the area, they are unconformably overlain by Cretaceous strata. In gen-

eral, the sedimentary wedge changes from shaly rocks in the Mackenzie-Richardson Mountains region to carbonates and ultimately to evaporites on the craton, and for about half of the area these rocks are effectively sealed by Upper Devonian and Cretaceous shales.

On the craton the structure is simple. Regionally the strata dip gently westward at a few tens of feet per mile and are locally dislocated by faults or folds of low structural relief. An exception is in the area north of Great Bear Lake, where, in the Colville Hills, there are several large anticlines, some faulted, with several hundred feet of structural relief. Within the craton there is at least one broad ancient arch—the Tathlina high; there may be others. The western part of the area, adjacent to the Mackenzie Mountains, has been compressed into a series of large open folds and high-angle faults.

Geological conditions favourable for the generation and entrapment of large amounts of petroleum were almost certainly present. The subsequent geological history of the region, however, has, in various ways, drastically reduced the probability of preservation of many of these accumulations.

The Middle Devonian barrier reef complex of southernmost Northwest Territories has been breached at its up-dip end and erosion has destroyed the reservoir area most favourable for giant fields. Remaining potential of this area appears to be limited to fields of relatively modest size. Many such fields are known in northeastern British Colombia and adjacent Northwest Territories.

The carbonate-shale front which lies parallel to the Southern Mackenzie Mountains coincides with the fold belt and thus much of the favourable reservoir rock is breached on the structures or nearby. The Beaver River and Pointed Mountain anticlines lie within this belt and both contain large gas reserves. However, for various reasons, the discovery of many other traps of this size is considered unlikely. Adjacent to the Richardson Mountains this same facies front is at a very early stage of exploration and there are good possibilities for major gas potential in this area.

The carbonate-evaporite transition within the Devonian succession forms a wide belt extending in a generally north-south direction across most of the Northwest Territories mainland. For most of its length the facies transition lies at shallow depths and outcrops extensively. It is thus probable that much of the petroleum once trapped has escaped due to erosion or leaching of the evaporite seal. There have been a few small shows of oil from wells drilled within this belt.

The favourable reservoir rocks within large structures in the Franklin Mountains and Colville Hills have been breached. Prospects there are thus limited to the deeper section, stratigraphic flank traps or to complex fault traps.

The Norman Wells field is an example of a reef within a shale facies. It occurs on the flanks of one of the Franklin Mountain structures and porosity is enhanced by fracturing. There is a good possibility of finding more such traps but they can be expected to be of small to moderate size. Several similar reefs have been located in the undisturbed area, but to date minor gas shows have been encountered.

The potential for petroleum related to unconformities is as yet inadequately explored and offers hope for several small to moderate sized fields. A well west of

Fort Norman yielded medium gravity crude in carbonates immediately below Cretaceous shales. A similar prospect is the area where Ordovician carbonates are sealed by Lower Devonian evaporites.

The Eagle Plains Basin is a rather special case. The Upper Cambrian to Middle Devonian carbonates are present as in adjacent areas and a carbonate-shale front lies along the west side of the Richardson Mountains adjacent to the eastern margin of the basin. Upper Paleozoic and Mesozoic source and reservoir rocks are present and are highly petroliferous as indicated by discoveries and geochemistry. There are numerous facies and structural trapping possibilities. One limiting factor lies in the relatively small size of the structural basin.

The northernmost part of the northern mainland has been inadequately explored. Lower and middle Paleozoic carbonates like those to the south are present but favourable facies variations appear to be absent. An extensive unexplored deltaic succession is present within the Mesozoic rocks of the Anderson-Horton Rivers area which may have some gas potential.

7. *Alberta, Saskatchewan and Manitoba.* This is, perhaps, the best known area of Canada from the point of view of subsurface geology and one that is in a mature stage of exploration. The petroleum prone region of Alberta lies in the southern part of the western Canada sedimentary basin, while Saskatchewan and Manitoba are on the northern side of the Williston Basin which extends over the international boundary into Montana and North Dakota. Both of these basins are of simple structure with low regional dips. A fairly large part of both basins lies at relatively shallow depths and has little petroleum potential. This has been well documented by exploration to date. The oil and gas in both basins occurs mainly in stratigraphic traps in a variety of configurations.

The Williston Basin in Saskatchewan and Manitoba is of the craton centre type and characteristically is of relatively low petroleum potential. The best prospects have been thoroughly tested and the remaining potential seems to be relatively small.

In Alberta, there are still reasonable expectations for additional hydrocarbon discoveries to the extent of an additional 30 to 40 per cent of what has already been found. The future reserves can be expected to be found in stratigraphic traps less obvious and smaller than those found to date, and in deeper parts of the basin that have not, up to now, been thoroughly tested. One can therefore anticipate higher finding costs in the future. This future potential likely will be found in bioherms, unconformity traps, up-dip pinchouts of porosity in both sandstones and sheet porosity in carbonates where lateral seals are provided.

8. *Northeast British Columbia.* This area lies in the deeper part of the western Canada sedimentary basin. Probably because the region was deeply buried in the past and because, in places, it displays relatively high geothermal gradients, the discoveries to date have been dominantly gas. It is anticipated that this also will be true in the future. Most of the previous drilling has been on surface structures or structures easily found by geophysical methods. The primary trapping configurations, however, are in many cases stratigraphic. Since most of the obvious structures have been tested in the plains area, future exploration will have to

concentrate on stratigraphic traps, some at considerable depth. A number of obvious structures remain to be tested in the disturbed belt of British Columbia, but what exploration has taken place in this region to date has not been encouraging. At best, one could hope that future additions to reserves will be up to an amount equal to what has aleady been found. Again, these additions, for reasons discussed above, will result in relatively high cost energy.

9. *Bowser Basin, British Columbia.* This basin is the largest of several intermontane basins lying within the Cordilleran area of British Columbia. It contains a very thick sequence of Jurassic and Cretaceous clastic rocks, overlying the siliceous carbonates in the Permian Cache Creek Formation. One well has been drilled in this basin without success but it was not considered to be diagnostic and another is currently underway. The objective is to find fracture porosity in perhaps the Cache Creek or Triassic carbonates on large anticlinal structures. The source rock characteritics of the overlying beds are not particularly good and the possibility of encountering adequate reservoirs is low. The geological history of the region indicates that the geothermal gradient has been relatively high in this region so only gas is anticipated. Moderate reserves have been assigned to the basin but at a relatively low probability of being present.

10. *Offshore West Coast.* Two basins are known on the west coast of British Columbia—the Queen Charlotte Basin, lying between the Queen Charlotte Islands and the mainland and the Tofino Basin, lying off the west coast of Vancouver Island. Another fairly large basin is present on the continental slope but little of its geology is known and, because it cannot be reached with current technology, it has not been considered in this evaluation. The Queen Charlotte and Tofino Basins have both been tested by a number of wells, with no success. Without going into detail, it can be said that the results of these tests were not geologically encouraging and that it is difficult to assign more than a token potential to these basins, with a very low probability of significant hydrocarbon being found. This probability could, of course, change significantly upward if additional drilling or geophysical work were to turn up any encouraging new evidence that might suggest some of the prolific basin configurations to be found at other localities on the Pacific Coast, particularly in California.

Eastern Canada

The sedimentary basins of Eastern Canada cover an area of 1,375,000 square miles and contain approximately 2.5 million cubic miles of sedimentary fill. Studies to date indicate geological conditions in these basins are not conducive for the generation and entrapment of hydrocarbons in above average volumes and some sub-basins may be totally devoid of recoverable oil and gas.

In the offshore basins of Eastern Canada, the "pull-apart" origin of the region, together with the long period as an open continental margin with relatively slow rates of deposition, detract from its likelihood of being an above average petroleum province, although sub-basins within it may be extremely prolific. Extensive geological and geophysical exploration to date have yet to culminate in a major oil or gas discovery although several significant finds have been made. Large volumes of hydrocarbons almost certainly exist in the East Coast basins but due to the

extremely high exploration and development costs the percentage that can be produced economically may be below average.

The eastern onshore and maritime basins which lie within or on the eastern periphery of the Canadian continental cratonic area, are characterized by first cycle lower Paleozoic carbonate platform sediments and, in part, overlain by sequences of terrigenous clastics. They are judged generally to have low hydrocarbon potential per unit volume of sedimentary rock due to the lack of significant facies changes and extended periods of emergence.

11. *Scotian Basin (including Sydney Basin).* The Scotian Basin contains a thick basal sequence of Lower Jurassic redbeds and evaporites with almost no hydrocarbon potential. These are overlain by Middle and Upper Jurassic carbonates and clastics probably containing good source bed potential but possibly lacking favourable reservoir conditions. This basin also contains a very thick sequence of sandstones and shales that are deltaic in part and which have yielded a large number of oil and gas shows and two discoveries in the course of recent drilling. The Sydney Basin, which is underlain by Carboniferous sediments and evaporites with relatively low potential, occurs in the northeastern part of this area.

The composition and paleodepositional environment of the sediments, together with the type of organic material present, indicate the Scotian Basin will probably yield above average quantities of gas, relative to oil. Seismic profiles indicate relatively few giant structures but a large number of 5-10 square mile salt piercement structures occur. Larger (10-20 square mile) but lower amplitude deep-seated structures occur, as do rollover features into faults. Undoubtedly, abundant stratigraphic traps also occur in this area. As a result average pool sizes may be in the order of the Sable Island and Thebaud discoveries with relatively few very large accumulations.

12. *Avalon Uplift and Flemish Cap.* Because of the large area with less than 4,000 feet of sedimentary cover, the Avalon Uplift province is considered to have a relatively low potential for the accumulation of hydrocarbons of economic significance. The stratigraphic succession in this region consists of deformed and partially eroded Carboniferous, Jurassic, and possibly Triassic sediments overlain by Cretaceous and Tertiary clastics. Seismic data has indicated no piercement structures within this province. The main prospects will probably be related to the major unconformities and to fault controlled structures. Potential in any single structure could be large but, in general, because of a relatively long period of erosion during the Mesozoic, the overall potential of this area is considered below average. The thick sedimentary sequence lying beneath the slope, along the east side of the Grand Banks, could have above average hydrocarbon potential but reconnaissance seismic data indicates a paucity of structural traps.

13. *East Newfoundland Basin.* The East Newfoundland Basin, although appearing to have the basic criteria for a major hydrocarbon province, has yet to be tested by drilling so there is no control on the stratigraphy, age, depositional environment, or source rock potential of the sedimentary rocks. Subsurface mapping from seismic data indicate that this area has, in part, been a semi-restricted basin during much

of its history and, as such, may have above average source-bed potential. Isopach maps indicate periods of subsidence during which at least some of the salt domes and fault blocks had positive movement, a situation which is considered ideal for early accumulation of hydrocarbon. Sediments within economic drilling range are thought to be mainly clastics of Cretaceous and Tertiary age. Regional seismic data indicates that there are relatively few structures underlying this area; those that are present, however, are generally larger than in the Scotian Basin, giving the possibility for several large oil and gas fields. Three major types of structural traps are apparent: (a) those associated with large deep-seated salt structures in the central part of the basin; (b) a series of large basement fault block structures along the west and southeast flanks of the basin; and (c) those associated with a major hinge line paralleling the west side of the basin.

14, 15. *Labrador and Baffin Island Shelf and Slope*. The shelf/slope provinces of Labrador and Baffin Island comprise an area of 200,000 square miles underlain by sedimentary sequences. The two regions are discussed together because of their geological similarities. Regional seismic data indicates the presence of a thick sedimentary prism paralleling the coastline throughout the entire area with possible deltaic wedges lying off Hudson Strait-Frobisher Bay-Cumberland Sound and Lancaster Sound. Most of the sediments, to depths of 25,000 feet, are assumed to be Mesozoic and/or Cenozoic in age but there is no well data presently available to confirm this. With the exception of initial deposition over an irregular basement surface, and areas influenced by deltaic sedimentation, these provinces may have been open marine shelves throughout much of their history and, as such, may have below average hydrocarbon potential.

Another area which is probably beyond both drilling and production technology is the uppermost portion of the Continental Rise in a narrow band from Georges Bank to Baffin Bay. Sedimentary thicknesses in this zone may average 15,000 feet but these lie beneath 10,000 feet or more of water. Seismic profiles reveal the presence of structures but the rocks are expected to be mainly shale and siltstone with turbidite deposits constituting the only reservoirs. Potential estimates for the Continental Rise are included in the Baffin Island Shelf and Slope Basin.

16. *Hudson Platform*. The extensive (460,000 square mile) sedimentary basins of the Hudson Platform are nearly twice the area of the Province of Alberta, yet the average thickness of sediments in the basins is less than 2,000 feet. Potential reservoir rocks exist in biogenic carbonates of Middle Silurian and Devonion age, but these are at or very near surface over a considerable portion of the area. The main area of interest for hydrocarbons is a large anticlinal structure which trends northwest across the central portion of Hudson Bay. This feature was probably formed by block faulting in Early Devonian time and consequently reservoir rocks in the core of the structure may be lacking or considerably limited due to a prolonged period of erosion. This, together with the monotonous predominant carbonate lithology of the lower Paleozoic rocks; a possible lack of competent traps; and, for purposes of comparison, no similar basins with significant amounts of oil or gas; results in a relatively low ultimate hydrocarbon potential.

17. *St. Lawrence Platform*. The St. Lawrence Platform is divided geographically into three divisions. The eastern division, embracing the Anticosti Basin, contains thick Cambrian, Ordovician and Silurian sequences comprised of carbonates, shales and sandstones. The basal Paleozoic (Cambrian) clastics are potential reservoir rocks which may form stratigraphic and unconformity traps beneath Lower and Middle Ordovician carbonate rocks. Structural traps may be present in Cambrian and Ordovician rocks in the south and eastern parts of the basin where tectonic activity has been the most extensive. The central region of the Platform is the Quebec Basin and adjacent Ottawa Embayment which contain Cambrian and Ordovician carbonates, shales and sandstones that are lithologically similar to correlative formations in the Anticosti Basin. Basal Paleozoic (Cambrian) clastics are again the main potential reservoirs and these are being explored in structures formed by normal faulting and in possible unconformity traps beneath the over-thrusted Taconic allochthone in the southern part of the basin.

The western division of the Platform comprises segments of the Michigan Basin and Allegheny Trough as well as the intervening Algonquin Arch, which underlies most of the inter-Great Lakes region of southwestern Ontario. Presently producing reservoir rocks are Cambrian sandstones; dolomitized fracture systems in Middle Ordovician carbonate rocks; porosity and permeability traps in Lower Silurian sandstones; Middle Silurian bioherms and salt solution structures in Middle Devonian carbonate rocks.

18. *Maritime Basins*. Within the Appalachian Geosyncline, in the Gaspé Trough, Silurian and Devonian sandstones, siltstones, shales and carbonates are strongly folded and faulted. In the eastern part of the trough numerous surface oil seeps occur and good shows were encountered in drilling but no commercial discoveries have yet been made. In the western Gaspé, Silurian reefs provide the main exploration target. The highly faulted Paleozoic sediments and possible lack of trapping mechanisms throughout the entire Gaspé Trough result in a low petroleum potential for this region.

The intermontane Magdalen Basin, underlying the southern Gulf of St. Lawrence and adjacent onshore areas, and Acadian Basin, lying mainly beneath the Bay of Fundy, comprise clastics, evaporites, and minor carbonates of Permo-Carboniferous and Triassic age. These rest on a basement complex of Ordovician, Silurian and Devonian age rocks that were deformed and metamorphosed during the Acadian Orogeny. The relatively thick sedimentary sequence is composed largely of redbed clastics of continental origin and, with the exception of thick coal measures within the Pennsylvanian strata and marine beds of Mississippian age, hydrocarbon source rocks appear to be relatively limited. The predominant hydrocarbon in these basins is most likely to be gas.

Potential trapping mechanisms are the diapiric structures that have formed in considerable numbers in the eastern offshore part of the Magdalen Basin; possible stratigraphic traps such as the Stony Creek field near Moncton, New Brunswick, that has continually produced small amounts of both oil and gas for more than 60 years; and fault-controlled structures flanking the numerous basement uplifts.

Comparisons with Other Estimates

Three detailed estimates of Canada's oil and gas potential are available for comparison with the 1973 estimate by the Geological Survey of Canada, as discussed in the previous sections of this appendix. Estimates prepared by the Canadian Petroleum Association (1969), the Geological Survey of Canada (1972), and estimates prepared in 1973 by the Canadian Society of Petroleum Geologists (1973 A)* are compared with the GSC (1973) estimate in Table 3. Each of these approaches, involving different methods and data, give somewhat different values.

The Canadian Petroleum Association (1969) Estimate

The CPA (1969) estimate was one of the first published, although there had been earlier attempts.

The estimate was purely volumetric and derived by multiplying figures representing the volumes of sediment covering large regions, each of which includes one or more sedimentary basins and a variety of geological configurations, by a yield factor in barrels of oil per cubic mile. The yields used were selected as representative of the average for such large heterogeneous regions. The resulting ultimate potential oil "reserves", expressed as barrels, were multiplied by a factor to give an ultimate potential gas "reserve" in cubic feet. The gas-oil factor is considered to represent the average proportion of gas to be discovered in each region and averaged 6,000 cubic feet. The study included the sedimentary volume to depths of 25,000 feet and, offshore, under a water cover of no more than 600 feet.

In 1972, when Energy, Mines and Resources was in need of information on Canada's oil and gas potential, the Canadian Petroleum Association figures were the best available published estimates. They were broken down into eight basins only and published without sufficient detail to permit the Department to appraise fully the basis of the potential determination and to conduct regional economic analyses.

The Geological Survey of Canada Estimate (1972)

The Geological Survey of Canada then embarked on a systematic program of potential determination that produced, by the end of February, 1972, figures representing first departures from a strictly volumetric approach and a breakdown into thirty-two basins permitting regional analysis. The volumetric method consists in the determination of the volume of sedimentary rocks found in each basin, which volume is multiplied by a yield factor to arrive at an oil and gas potential estimate for the basin. The yield factor for each basin is determined on the basis of knowledge of the basin in the context of a worldwide basin classification scheme. The GSC adopted a preliminary basin analysis approach for the determination of geoscientific facets of any one basin; it used the resulting informa-

*A late estimate by the Canadian Society of Petroleum Geologists (1973B) is discussed in the text to follow but not included in Table 3.

TABLE 3

ULTIMATE RECOVERABLE OIL AND GAS POTENTIAL
COMPARISON OF GSC, CPA AND CSPG(A) ESTIMATES
(based on 1973 GSC regions)[1]

	Vol. (cu. mi.)	Oil (billion barrels)	Gas (trillion cu. feet)	BOE (billion barrels)	BOE Yield Factor (bbls./cu. mi.)
1. Arctic Islands & Coastal Plain (North) (Basins 1 to 4)					
GSC 1973	1,151,000	20.3	242.0	60.4	52,500
CPA 1969	790,000	43.5	260.7	87.0	110,100
GSC 1972	1,260,000	49.3	327.4	102.3	81,000
CSPG[2] 1973		28.6	208.8		
2. Beaufort-Mackenzie (Basin 5)					
GSC 1973	90,000	6.2	93.5	21.8	242,000
GSC 1972	177,000	14.7	117.2	34.2	193,000
CSPG 1973		8.0	64.0		
3. Western Canada (Basins 6 to 10)					
GSC 1973	1,027,000	22.2	120.3	42.2	41,100
GSC 1972	985,000	28.6	207.4	61.0	61,900
CSPG 1973		25.0	155.5		
2. and 3.					
CPA 1969	1,105,000	47.4	283.8	94.7	85,700
4. Offshore East Coast (Basins 11 to 15)					
GSC 1973	1,790,000	47.5	307.1	98.9	55,200
CPA[3] 1969	450,000	24.8	149.9	49.8	110,600
GSC 1972	2,003,000	38.5	229.6	75.8	37,800
CSPG[3] 1973		22.1	132.6		
5. Hudson Platform (Basin 16)					
GSC 1973	167,000	1.5	7.3	2.7	16,700
CPA 1969	145,000	2.9	17.4	5.8	40,000
GSC 1972	145,000	1.5	8.7	2.9	20,000
CSPG 1973 (Included in Area 1 above)					
6. Eastern Canada Onshore (Basins 17, 18)					
GSC 1973	245,000	1.5	12.7	3.7	15,100
CPA 1969	151,500	2.3	13.0	4.5	29,700
GSC 1972	123,500	1.8	15.8	4.4	35,600
CSPG 1973		1.5	16.6		
Totals:					
GSC 1973	4,470,600	99.2	782.9	229.7	51,400
CPA[3] 1969	2,040,000	120.9	724.8	241.8	118,500
GSC 1972	4,693,500	134.4	906.2	280.6	59,800
CSPG[3] 1973	3,538,000	85.2	577.5	181.5	51,300

[1]Basin numbers in brackets refer to basins shown in Figure 1 and Table 2.
[2]CSPG(A) Estimate—includes Hudson Platform.
[3]Offshore continental slopes not included.

tion to qualify the volume and yield factor, and commenced on a probabilistic approach by determining minimum, maximum and "best estimate" figures of potential for each basin.

Confidence in the method was indicated as eventually the process led to the systematic basin analysis, the identification of plays, and the probabilistic curve determination of the 1973 exercise. The GSC (1972) results did not differ greatly from the CPA overall figures, although there are differences between specific regions. They provided the Department with a first appraisal in wanted details whereby it could commence economic analysis of potential. It did so with the awareness that development in appraisal method, increase in geoscientific information, and results of exploration would lead to potential re-appraisal in 1973 and, indeed, each subsequent year.

The Canadian Society of Petroleum Geologists Estimates (1973 A & B)

The figures in Table 3 (CSPG, 1973A) were released by the CSPG in a press conference in Calgary on March 19, 1973. They are based on a summation of a series of estimates in detailed papers by 27 authors covering all the sedimentary basins of Canada, shortly to be published in a volume entitled "Future Petroleum Provinces of Canada". These estimates were derived using a variety of methods, including volumetric, and reported in various ways. Each was based on a sound knowledge of the geology of each basin. Individual estimates were compiled and modified to achieve overall consistency within a basin classification.

On the occasion of the press conference presenting the CSPG figures it was mentioned that there was incomplete agreement within the CSPG regarding the estimates. Subsequently, in a submission to the Science Council of Canada dated March 27, 1973, the CSPG presented a second set of figures (CSPG, 1973 B) based, apparently, upon an entirely different approach. The latter approach attempts to estimate potential volumes of oil and gas *in place* using 10% and 90% confidence limits. No estimates of *recoverable* potential are provided. The latest CSPG (1973 B) estimate is given in Table 4.

Although oil and gas recovery factors are constantly increasing due to improving technology and price increases, as a rough rule of thumb, recovery factors of 33% for oil and 85% for gas might be applied to the above estimates to place them on a roughly comparable basis with the figures in Table 3. This would result in a potential recoverable oil range of 23 to 98 billion barrels and a potential recoverable gas range from 157 to 655 trillion cubic feet of raw gas. These ranges are too broad to provide a basis for further analysis. They do, however, indicate that the recent CSPG view, asusming only a 10% probability of occurrence of potential in the order of 98 billion barrels of oil, is more conservative than are the other estimates reported to date. Since estimation methodology is not discussed in the latest CSPG brief nor is a breakdown of potential by areas presented, it is difficult to compare these latest figures with the previous estimates.

TABLE 4

CSPG ESTIMATES OF RESERVES "IN PLACE"
(March 27, 1973)

	Oil *Billion Barrels* (in place)	*Raw Gas* *Trillion Cubic Feet* (in place)
Proved Reserves		
Present Reserve Remaining	39	99
Cumulative Production	5	21
Potential[1]		
Mature Areas[2]	5–50	15–150
Frontier	20–200	50–500
Total Proven and Potential	69–294	185–770

[1]In the potential estimates the first figure shown is at a 90% "certainty" of occurrence, the latter at a 10% "certainty" of occurrence.
[2]Northeastern British Columbia, Alberta, Saskatchewan, Manitoba, Niagara Peninsula area of Ontario.

Summary. Table 3 shows the various estimates grouped in broad geographic categories for comparative purposes. It should be noted that:

the apparent discrepancy in sedimentary volumes in offshore estimates by CPA are due to their limiting such estimates to areas lying beneath less than 600 feet water depth;

CSPG (1973 A) estimates shown also *exclude* sediment volume below the continental slope of the Atlantic offshore.

Both Geological Survey estimates (1972 & 1973) include Atlantic offshore slope sediments, thus encompassing a greater volume of sediments than either of the other estimates.

The 1973 study by the Geological Survey, as described previously in detail, was an improvement on its original estimate; it adopted a probabilistic approach and was based on comprehensive basin analysis studies, including geochemistry and geophysics.

Each successive estimate can be expected to improve upon the previous, owing to increased geological knowledge resulting from new data and interpretations, and to improvements in methodology. Analysis of further data and generation of further research on a continuing basis make it likely that there will be changes year by year in the shape of the curves generated for each basin and in the overall total for Canada. Changes will be caused by two classes of variables:

Progressive changes which result from modifications to the curves for each basin as knowledge and interpretation improve. These will include changes

in the absolute volume of sediments, changes in opinions on the classificatory rank of the basin, appreciation of new or re-evaluation of previously determined oil and gas systems within the basin, knowledge of deeper structures or previously unknown structures. Changes are less likely to be drastic in the better-known basins but, in areas which have been relatively little explored, they could be of major significance.

Radical changes in the probability curve for a basin following further exploration activity. Thus, the probability of finding a super giant field in a particular basin may presently be shown as 5 per cent. The discovery of such a field would immediately change the curve both for proven reserves, and for probability of finding further large fields. The curves for many of the sedimentary basins of Canada currently indicate the possibility of a potential very much larger than the current mean but at a relatively low probability. On the other hand, additional drilling, combined with geological or geochemical interpretation, may well indicate that the current curves are over-optimistic and must be reduced, perhaps radically.

(B) COAL

The coal reserves of Canada, south of 60° north latitude, are estimated at 120.2 billion short tons (Table 1). Saskatchewan, Alberta and British Columbia contain some 118.7 billion tons of coal of all ranks, accounting for 97.7 per cent of Canada's reserves (Tables 3, 4 and 5). The locations of Canada's coal deposits are shown on Figure 1.

The estimates of reserves have been established in three categories of measured, indicated and inferred, as defined hereunder and, in addition, by only including coal that occurs within defined limits of minimum seam thickness and maximum overburden thickness. These limitations vary between coalfields because of the highly variable conditions that are encountered in the widely distributed coalfields in Canada. They reflect the economic and technologic restraints, learned from past experience, that would preclude the extraction at the present time of the coal occurring outside the limits. Also excluded from the reserve estimates are deposits, such as those north of 60° north latitude, for which there are insufficient data to permit estimation of resources. They are discussed only briefly in this report. Hence the reserves reported here are conservative estimates and do not represent the ultimate coal potential of the nation. On the other hand, it must be remembered that these are geological estimates and only a relatively small percentage may be economically recoverable.

In this review much of the information relative to western Canada's coal reserves was taken directly from the Latour and Chrismas 1970 report, G.S.C. Paper 70-58.

Canada's coal resources include coal of all ranks and their distribution is widespread as shown on Figure 1.

ERRATUM

Map on page 57 should appear on page 254 and vice versa.

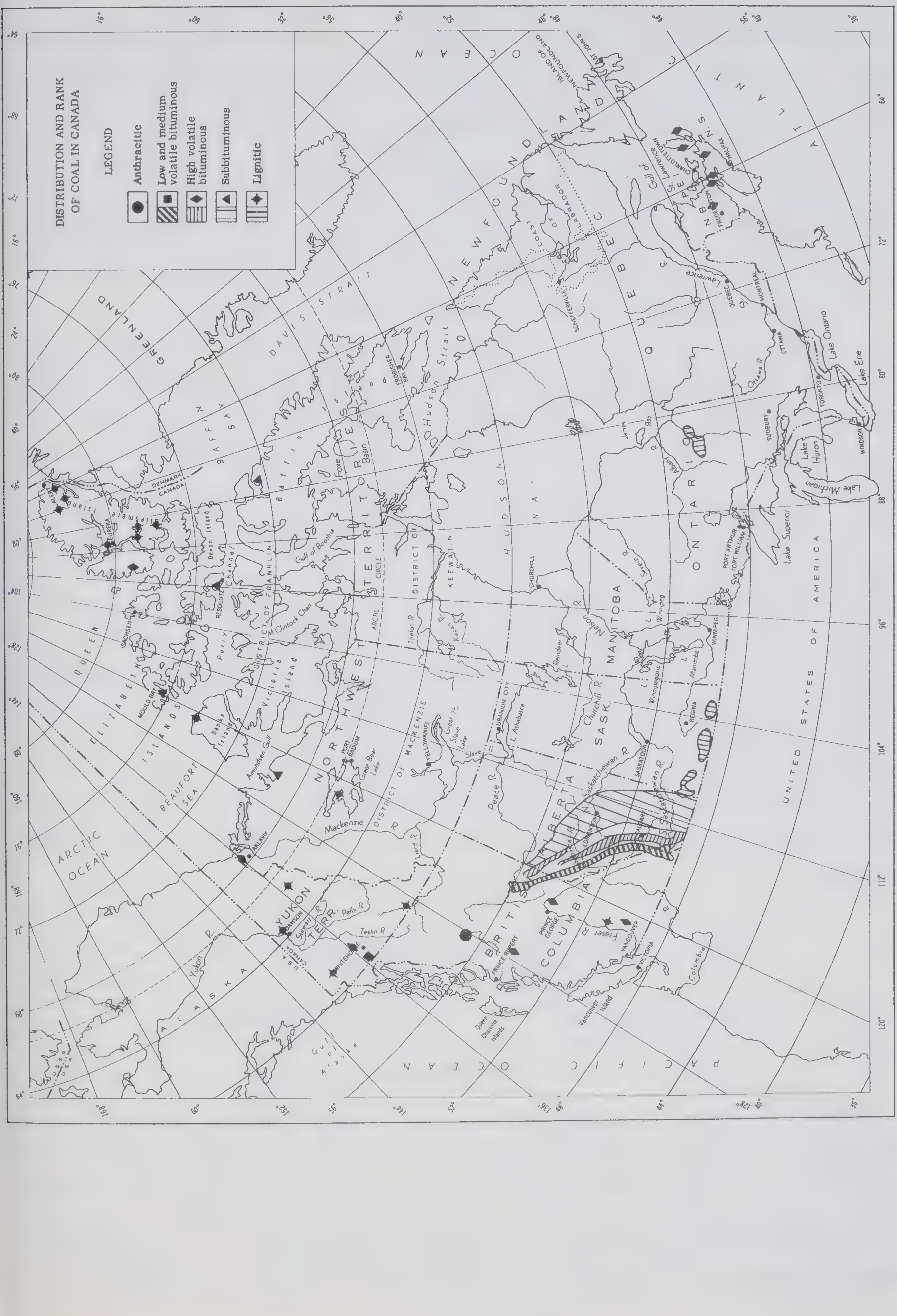
DISTRIBUTION AND RANK OF COAL IN CANADA
LEGEND
Anthracitic
Low and medium volatile bituminous
High volatile bituminous
Subbituminous
Lignitic

Figure 1

Definitions

The resource estimates are divided into the following categories:

1. *Measured (Proven) Reserves*—Measured reserves are those for which tonnage is computed from dimensions revealed in outcrops, trenches, mine workings and drillholes. The points of observation and measurement are so closely spaced, and the thickness and extent of the coal are so well defined, that the computed tonnage is judged to be accurate within 20 per cent of the true tonnage. Although the spacing of the points of observation necessary to demonstrate continuity of coal differs from region to region according to the character of the coal beds, the points of observation are, in general, about half a mile apart.

2. *Indicated (Probable) Reserves*—Indicated reserves are those for which tonnage is computed partly from specific measurements and partly from projection of visible data from a reasonable distance on the basis of geologic evidence. In general, the points of observation are about 1 mile apart, but they may be as much as 1½ miles apart for beds of known continuity.

3. *Inferred (Possible) Reserves*—Inferred reserves are those for which quantitative estimates are based largely on broad knowledge of the geologic character of the bed or region and for which few measurements of bed thickness are available. The estimates are based primarily on an assumed continuity in areas remote from outcrops of beds, which in areas near outcrops were used to calculate tonnage classed as measured or indicated. In general, inferred coal lies more than 2 miles from the outcrop or from points for which mining or drilling information is available.

The term "rank" refers to a classification of coal based upon the degree of metamorphism that the original vegetal matter has undergone to produce a coal as found today. Thus, various stages of metamorphism are identified through the series lignitic, sub-bituminous, bituminous and anthracitic and these are based on the percentage of fixed carbon and calorific value of the coal calculated on a mineral-matter-free basis. The rank of a coal should not be confused with the quality. The latter term refers to characteristics of a coal, such as ash content, sulphur content, coking properties, etc. which may or may not be present in coals of any rank.

Estimates of Reserves

Description of Coal Areas or Coalfields

1. Nova Scotia

Sydney Coalfield. This field has twelve coal seams that are considered to be mineable at least in part of their extent. The seams dip consistently seaward and outcrop in a narrow belt that extends along the shore for about 36 miles. The belt has a sinuous character due to northeasterly-plunging open folds that have been imposed on the strata. Because of this sinuous character the seams in places outcrop in the landward area and in other places outcrop in the seaward area.

TABLE 1

SUMMARY OF COAL RESERVES OF CANADA BY PROVINCE

(*Thousands of short tons*)

Province	Measured	Indicated	Inferred	Total
Nova Scotia	126,000	466,000	684,000	1,276,000
New Brunswick	10,000	—	—	10,000
Ontario	240,000	—	—	240,000
Saskatchewan	291,500	7,024,000	4,698,400	12,013,900
Alberta	2,203,900	32,096,100	12,940,200	47,240,200
British Columbia	7,328,600	11,175,400	40,953,000	59,457,000
Total	10,200,000	50,761,500	59,275,600	120,237,100

TABLE 2

SUMMARY OF NOVA SCOTIA COAL RESERVES

(*Thousands of short tons*)

	Measured	Indicated	Inferred	Total
Sydney	126,000	430,000	666,000	1,222,000
West Coast Cape Breton	—	20,000	7,000	27,000
Pictou	—	4,000	11,000	15,000
Springhill	—	6,000	—	6,000
Joggins	—	6,000	—	6,000
Total	126,000	466,000	684,000	1,276,000

TABLE 3

SUMMARY OF SASKATCHEWAN COAL RESERVES

(*Thousands of short tons*)

	Measured	Indicated	Inferred	Total
Estevan	291,500	1,044,400	487,200	1,823,100
South-Central	—	5,376,000	3,864,000	9,240,000
Southwest	—	603,600	347,200	950,800
Total	291,500	7,024,000	4,698,400	12,013,900

TABLE 4

SUMMARY OF ALBERTA COAL RESERVES

(*Thousands of short tons*)

	Measured	Indicated	Inferred	Total
Plains Area	1,221,800	6,197,300	2,530,000	9,949,100
Outer Foothills Belt	—	6,278,600	3,043,700	9,322,300
Inner Foothills Belt				
North (Luscar Fm)	542,000	7,426,500	3,535,400	11,503,900
South (Kootenay Fm)	440,100	12,193,700	3,831,100	16,464,900
Total	2,203,900	32,096,100	12,940,200	47,240,200

TABLE 5

SUMMARY OF BRITISH COLUMBIA COAL RESERVES

(*Thousands of short tons*)

	Measured	Indicated	Inferred	Total
Southeastern	6,930,500	10,402,300	40,033,200	57,366,000
South-Central	373,600	395,900	353,200	1,122,700
Central	12,000	4,600	119,700	136,300
Northeastern	12,500	372,600	446,900	832,000
Total	7,328,600	11,175,400	40,953,000	59,457,000

The coal in this field is high volatile "A" bituminous by Astor Rank classification. Of the twelve seams included in the estimate only one, the Point Aconi seam, has not been mined. Two seams, the Harbour and the Phalen, have been mined more extensively than the others. There are two reasons for this: first, the coal from these seams has a lower sulphur content and is more favourable for the manufacture of coke; and second, the two seams maintain higher mineable thickness over a greater area than do the others.

The more easily mineable coal has been extracted so that the land area now contains very limited reserves and the bulk of the reserves for the province are located in the submarine areas of the Sydney coalfield.

The reserves of this field are shown in Table 2 and include coal seams not less than 3 feet in thickness to a maximum depth of 4,000 feet.

Western Cape Breton Island Coalfields. There are four small coalfields scattered along the west coast of Cape Breton Island. From south to north they are Port Hood, Mabou, Inverness, and St. Rose-Chimney Corner. There are not sufficient reserves in any one field to allow for large scale mining operations. The coals are lower in rank and higher in sulphur than the Sydney coals. The quality of the coal seams, their inclination and almost entirely submarine position, restrict their economic importance. The resources shown in Table 2 includes

coal seams with a minimum thickness of 3 feet and maximum overburden thickness of 4,000 feet.

Pictou Coalfield. This field is considered to be mainly mined out and there now remains only a very small amount of accessible coal. The figures in Table 2 include coal with a minimum thickness of 3 feet to a depth of 1,000 feet.

Springhill Coalfield. This field has been extensively mined and only small amounts of readily accessible coal remain. With the abandonment of the mines at Springhill the entries to the productive seams have been lost. Table 2 includes coal with a minimum thickness of 3 feet to a maximum depth of 1,000 feet.

Joggins Coalfield. The areas in this field where the seams were best developed and most easily accessible have been depleted by extensive mining and the remaining coal is of little significance. The small reserves in Table 2 include only coal with a minimum thickness of 3 feet to a depth of 1,000 feet.

2. New Brunswick

There is only one productive coal seam in this field and it only averages about 18 inches thick. The coal has an extremely high ash and sulphur content which severely limits its usefulness. The better part of this field has been mined out and the remaining reserves, based on an average seam thickness of 18 inches to a depth of 75 feet are relatively small as shown in Table 1.

3. Ontario

Ontario has but a single coal deposit which is situated in the region south of James Bay and is known as the Onakawana Coalfield. The coal is lignitic in rank, has a high moisture content but the sulphur content is relatively low. The deposits appear to be favourably disposed for mining by surface methods. One area has been drilled with a sufficient density of holes to permit calculation of measured resources as shown in Table 1. Outside of this area, there are a few reported occurrences of coal but knowledge of the thickness and extent of any such seams is so limited as to preclude an estimate of any category of reserves.

4. Saskatchewan

Saskatchewan's coal deposits, all lignitic in rank, occur in a belt along the southern edge of the province and are contained in the Ravenscrag Formation of early Tertiary age. This belt is the northern fringe of a large basin that extends through western North Dakota and eastern Montana. In Saskatchewan the coal measures are almost everywhere well covered with a mantle of glacial deposits, a factor that has hampered exploration.

The coal measures attained their best development in the Estevan area where eight seams are recognized of which only the upper four have thicknesses of five feet or more. All four have been mined in the Estevan area and production has been mainly by strip mining. In this area only has there been sufficient exploration to permit estimates to be made of measured reserves.

Westward from the Estevan area the seams become fewer and thinner. In the central part of the belt five seams are present whereas at the western end of the

belt only three seams are known. The areal extent of the various seams has not been determined.

The reserves are shown in Table 3. The measured reserves represent only that coal contained in seams of 5 feet or more in thickness at depths not greater than 150 feet from surface. The same limit of seam thickness applies to the indicated and inferred categories but the depth of overburden is extended to a maximum of 500 feet.

5. Alberta

Estimates of the coal reserves of Alberta indicate that the province contains about 40 per cent of the coal reserves in Western Canada or about 47 billion tons. Most of the reserves are of bituminous coal, but coals of all ranks from lignitic to anthracitic occur in the province. High volatile bituminous and higher rank coals, which constitute the greatest part of the reserves are located in the foothills belt and the mountain areas, whereas the sub-bituminous reserves occur in the central plains.

Because of the wide distribution of coal in Alberta the coal reserves are grouped according to three main districts: Plains Region, Outer Foothills Belt and Inner Foothills Belt.

Plains Region. The generally flat-lying seams of sub-bituminous coal of the Plains Region occur in both the upper Cretaceous Edmonton Formation and Belly River Group rocks. For the most part the measured coal reserves for this region are considered to represent those that can be recovered by strip-mining technique. The bulk of current production is supplied from strip mines in the Halkirk-Forestburg and Wabamun Lake districts.

It was thought that the coal seams underlying the Plains Region maintained their thickness over large areas with only very minor disturbance. Recent exploration suggests that though the coal zones are persistent over large areas the seams within the zones are quite lensy. Also in some instances glaciation has partially or entirely eroded the near surface seams and in other instances has fractured the coal, caused pronounced undulations in the roof and floor of the seam, or faulted the seam with considerable distortion.

In the Plains Region the opportunity exists for the delineation of far more coal reserves, but the problem is the mantle of glacial drift that covers the bedrock throughout most of the area. Delineation of coal reserves requires much detailed drilling. The present main use of sub-bituminous coal is for mine-site thermal power generation.

Measured reserves in the Plains Region includes only coal seams having a minimum thickness of 5 feet to a maximum thickness of cover of 150 feet. The Indicated and Inferred Reserves retain the same seam thickness parameter but extend the thickness of cover to 1,000 feet.

Outer Foothills Belt. The Outer Foothills Belt contains coal of high volatile bituminous rank. This coal is not good coking coal and, in the past, was used in large quantities by the railways, as well as for residential and industrial fuel. Most of the production in this belt came from the Coalspur and Saunders areas with small amounts from the Pincher Creek and Pekisko areas. No mines are presently

producing in this belt, and little or no exploration or development is being done as indicated by the absence of measured resources for this area in Table 4.

The parameters applied to the Indicated and Inferred Reserves of this belt are a minimum seam thickness of 5 feet to a maximum depth of 2,500 feet.

Inner Foothills Belt. Alberta's largest coal reserves lie within this region. The Inner Foothills has been subdivided into two groups: (1) southern part, which is defined by the areal distribution of the coal-bearing Kootenay Formation; (2) northern part, which is defined by the areal distribution of the coal-bearing Luscar Formation. The coal within these groups primarily ranges from medium to low volatile bituminous in rank with some semi-anthracite and high volatile "A" bituminous. Much of it is suitable for carbonizing for the metallurgical market. Mines that are presently producing coal in this belt are located at Coleman in the Crowsnest area, at Canmore in the Cascade area, at Luscar in the Mountain Park area, and at Grande Cache in the Smoky River area. Considerable exploration is being done along the total length of the belt.

The coal measures in this belt are exceedingly folded and faulted resulting in extreme irregularity in seam thickness and sometimes complete truncation of the seams. Mining is difficult owing to the frequently encountered steeply pitching seams, methane gas and associated strata stress releases or "bumps". In most cases, the coal must be mined by underground methods unless a near surface, shallow-dip-slope can be found. Considering the vast amount of unexplored land in this area it is foreseeable that the reserves of this area could be increased substantially and eventually comprise the largest reserve of coking coal in Western Canada.

The parameters applied to the Indicated and Inferred Reserves of this belt are a minimum seam thickness of 5 feet to a maximum depth of 2,500 feet.

6. *British Columbia*

In the last few years a great flurry of exploration and development by a number of companies has added significantly to our knowledge of the coal resources of southeastern British Columbia. The province now ranks first in terms of measured and total coal, possessing some 50 per cent of western Canada's reserves. Although the province contains many small, widely distributed coal deposits, recent activity has been directed mainly at the more extensive deposits in southeastern British Columbia.

Southeastern Area. The coal deposits of the southeastern part of the province are situated near the Alberta-British Columbia border adjacent to the Crowsnest coalfield of Alberta. In fact, the southeastern coal deposits are an extension of the Inner Foothills Coal Belt of Alberta.

For the most part coal in this area is medium volatile bituminous in rank, although it does range into the low volatile bituminous rank and to a limited extent, high volatile coal. Most of this coal makes excellent metallurgical coke and it is on this basis that coal companies have recently signed long term contracts for the export of large volumes of coking coal to Japan. This area contains Canada's largest known reserves of coking coal. In the vicinity of Natal, within the Fernie coal basin, coal mining has been carried on for many years by underground and strip methods. Here the coal seams range up to 50 feet in thickness and average about 20 feet.

The resource estimates for this area are shown in Table 5 and include coal not less than 5 feet in thickness to a maximum depth of 2,500 feet.

South-Central Area. Three small coal basins are included here for consideration: the Tulameen, Merritt-Nicola, and Hat Creek deposits. All three of the deposits are Tertiary in age but the rank of the coal is different in each: the Tulameen is sub-bituminous to high volatile bituminous; the Merritt-Nicola coal is mostly high volatile bituminous; and the Hat Creek coal is lignitic. Outcrops of coal are infrequent and the seams are normally covered with a great thickness of younger sediments and alluvium and, at Hat Creek, by younger volcanic rocks as well. The deposits are folded and cut by faults so that the total picture is one of difficult exploration. The Hat Creek deposits are unique in that they contain the thickest assemblage of seams so far known in Canada. At least five seams are known to be present and their aggregate thickness is in the order of 2,000 feet. It is recognized that these seams are not pure lignite, but instead contain many interbeds of clay. Nevertheless, they do constitute a deposit with a very high potential and, moreover, they do pose the possibility that some of the other scattered occurrences that have been reported elsewhere in British Columbia may be similar to the Hat Creek deposits.

The resources of the South-Central area are shown in Table 5 and include coal not less than 5 feet in thickness to a depth of 1,000 feet.

Central Area. At least 21 coal occurrences have been reported from this area but only two are considered to contain reserves within the definition set forth. Lower Cretaceous coal deposits occur in the vicinity of Telkwa and the coal is classified by rank as medium to high volatile bituminous. Mining experience over the past 25 years has shown the deposits to be intensely folded and faulted in some places and at some localities intruded by volcanic rocks.

The other deposit located in Bowron River is thought to be Tertiary in age but the coal is ranked as high volatile bituminous. A limited amount of exploration has been carried out in this area which, in part, indicates that the seams are rather irregular in thickness.

The resources of this area, as shown in Table 5, are not large and reflect the small areal extent of the deposits and the lack of information concerning them.

Northeastern Area. The coal deposits of this area were discussed along with those of the Inner Foothills Belt of Alberta. Because of the relative remoteness of the area, exploration has lagged behind that in the more accessible parts of the belt to the south. However, recent exploration in this area has indicated that the reserves are much greater than shown in Table V, but the data are not all available and a detailed appraisal has not been done.

Northern Area. In this remote part of British Columbia there is a coalfield known as the Groundhog Coalfield that has undergone very little exploration and data are so scarce as to preclude an estimation of resources within the definitions set forth in this review. However, because of its apparent size and thickness of seams it does present a relatively high potential for gross amounts of coal of low volatile bituminous and anthracitic rank. Opposed to these positive factors are such negative factors as very high ash content, seams with many rock bands and an area that has been subjected to much folding and faulting.

7. *Northern Canada Coal Occurrences*

Reliable reports of significant occurrences of coal in this large region are sufficient to indicate a very high potential of coal resources in northern Canada. Information on these occurrences is confined almost entirely to reports of seams exposed in outcrop. Distribution of these reported occurrences is shown on Figure 1, together with the rank of the coal as determined mainly by analyses of outcrop samples. It is significant that the coals are most often low in rank despite the fact that some of them are relatively old coals. Some seams show considerable thickness, up to 30 feet thick, and are thought to have good lateral extent.

The occurrences shown on the map are all those that are reliably known to have at least one seam that is 5 feet or more in thickness. Table 6 presents in brief form all that is known about the occurrence at each locality

TABLE 6

Locality	No. of Seams	Thickness of Seams (Feet)
1	1	6
2	2	6
		4–11
3	2	8
		30
4	1	5
5	2	9.6
		10.3
6	3	30
		10
		8
7	3	8
		9
		7
8	4	12
		13.5
		10
		18.5
9	1	7
10	2	15
		40
11	1	10–15
12	1	5
13	1	5
14	1	5
15	1	8
16	1	7
17	2	30
		15
18	1	20
19	1	8
20	1	20

Other Resource Estimates

The first estimate of coal reserves in Canada was prepared by Dowling (1913) for the 12th International Geological Congress. Dowling estimated Canada's reserves at more than 1.3 trillion tons based on coal seams with a minimum thickness of one foot to a maximum depth of 4,000 feet from surface. A far more comprehensive study of Canada's coal reserves was published by MacKay (1947) for the Royal Commission on Coal, 1946. MacKay's estimate of 49 billion tons of recoverable coal or 99 billion tons of coal in place was less than 10 per cent of Dowling's estimate. The reason for MacKay's lower estimate was that he used seam thicknesses and depths of cover that varied from coalfield to coalfield and did not include seams less than three feet thick. A later revision of MacKay's was made by Latour in 1960 for the Royal Commission on Coal, 1959. Latour included only a few changes where new information was available and also took into account tonnage produced between 1946 and 1959. Some of the economic factors that contributed to changes in the reserves of some coal areas were discussed also. In the earlier coal resource studies no attempt was made to report resources of the measured category. MacKay's report categorized the reserves as being either probable or possible. In 1967, P. A. Hacquebard prepared a short review of the coal deposits of Nova Scotia and New Brunswick, including a revision of reserves, for inclusion in Geology and Economic Minerals of Canada, 1970. His reserves were designated as probable recoverable reserves and were divided into two categories of readily accessible and less readily accessible but he did not define his terms. Finally, in 1969 Latour and Chrismas published the results of a study of the coal reserves of Western Canada. They introduced the terms measured, indicated and inferred and defined them, and their terms and definitions have been used in this review.

(C) URANIUM

This appendix defines the terms which are in common use for the classification of uranium ore reserves and resources, refers to the method by which reserves and resources have been determined, lists the presently accepted figures in the various categories, comments on the reserve figures, and lists the various types of uranium deposits which are likely to be important in Canada.

Definitions

The following two definitions were developed in 1964 by the ENEA (European Nuclear Energy Association) Working Party on Uranium Resources:— They are further subdivided, as to availability, within two price ranges, namely, up to \$10/lb U_3O_8 and between \$10 and \$15/lb U_3O_8. The definitions were revised in 1970 to restrict estimates to known uranium districts only.

1. Reasonably Assured Resources refer to uranium which occurs in known ore deposits of such grade, quantity and configuration that it can, within the given price range, be profitably recovered with currently proven mining and processing technology. Estimates of tonnage and grade are based on specific sample data and measurements of the deposits and on knowledge of ore-body

habit. Reasonably Assured Resources in the price category below $10 per pound are equivalent to Reserves in the mining sense.

2. Estimated Additional Resources refer to uranium surmised to occur in unexplored extensions of known deposits or in undiscovered deposits in known uranium districts, and which is expected to be discoverable and economically exploitable in the given price range. The tonnage and grade of Estimated Additional Resources are based primarily on knowledge of the characteristics of deposits within the same districts.

Source of Information

Deposits of energy minerals such as uranium are for the most part very difficult to assess relative to deposits of fossil fuels such as coal, oil and gas. Depth limitations on detection and exploitation of uranium deposits are much more severe. In addition, resource potentials cannot at the present time be estimated on a national basis by applying sets of factors to large volumes of rock in the way that the oil and gas potentials of sedimentary basins are estimated. As the base of geoscientific knowledge expands, then better and more comprehensive estimates will become possible.

The first assessment of Canadian uranium reserves was made in 1958 by J. W. Griffith *et al.* of the Geological Survey of Canada (GSC) for publication on the occasion of the Second United Nations International Conference on the Peaceful Uses of Atomic Energy (Geneva II). The estimates were given by geological type and in terms of tons of measured (proven), indicated (probable), and inferred (possible) ore, with average grades. In 1964, for the Third Geneva Conference (Geneva III) Griffith *et al.* revised their study, classifying the resources further as to exploitability at various price levels.

In 1964 the European Nuclear Energy Agency (ENEA), of which Canada is an Associate Member, set up the Working Party on Uranium and Thorium Resources for the purpose of preparing an assessment of the world's uranium and thorium resources. The report, the first of a now familiar series, was published in August 1965; the Canadian delegates to the Working Party adapted the Griffith *et al.* report to Geneva III for the purpose of the Canadian submission to the ENEA.

Coverage of these world studies was subsequently widened under the joint auspices of the ENEA and the International Atomic Energy Agency (IAEA). The fourth in the ENEA/IAEA series of world uranium resource assessments is to be published in 1973. The resource definitions and classifications by price (US $), first developed by the ENEA Working Party in 1964, have now become internationally accepted and are used by the Department of Energy, Mines and Resources in stating Canada's estimates of known uranium resources.

Several major sources of input data have been used in compiling the following table, including industrial information and governmental information comprising (i) historical production records, (ii) a geological appraisal of the Elliot Lake conglomerates, and (iii) forecasts of potential resources in less well known areas. These data were then assessed and used to produce aggregated national totals.

In preparing the following table, five principal types of uranium ores, one of which is further subdivided, have been considered separately. Each type has a characteristic mode of occurrence that influences the success of its estimation, exploration and exploitation. A tabular type of deposit in bedded rocks, for example, tends to be easier to exploit and less difficult to estimate than a type that occurs as irregularly distributed, discontinuous veins. Brief descriptions of the types of uranium deposits and their consequent features are given in a succeeding section, and are shown on Figure 1.

Reserves and Resources

URANIUM RESERVES AND RESOURCES IN CANADA
(as of December 31, 1972)

Price category ($/lb U_3O_8)	Reasonably assured resources (Reserves) (short tons U_3O_8)	Estimated additional resources (short tons U_3O_8)
Up to 10	241,000	247,000
10 to 15	158,000	284,000

When uranium exploration is launched once again in Canada on a substantial scale, additional resources will undoubtedly be discovered. Officials of Energy, Mines and Resources have estimated that perhaps a further 700,000 tons U_3O_8 might be found and recovered for less than $15 per pound.

For the long-term future it would be desirable to provide data for exploitable resources in the $15-$20 price range. In the Elliot Lake area, 100,000 tons of U_3O_8 may become available from material exploitable at a price of $15 to $20 per pound. The data are lacking because exploration has been oriented toward richer ores and money is seldom spent in measuring deposits that are far below presently exploitable grades.

Unlike coal, oil and gas, uranium is much more widely dispersed within the Earth's crust. There are immense tonnages of uranium occurring at concentrations of a few tens of parts per million in a variety of relatively common rock types. Even larger tonnages are contained in widespread granitic rocks at lower concentrations. Before such sources need be considered, however, it could become economically feasible to extract some of the 5,000 million tons of uranium dissolved in sea-water. Thus the potential uranium resources available to Canada are large indeed.

Types of Deposits

Conglomerate ores: Conglomerate uranium deposits consist of quartz-pebble conglomerate beds at or near the floors or basins of Proterozoic rocks. Most geologists believe that such deposits are fossil placers that were formed under special conditions, including an oxygen-free atmosphere. This condition may be

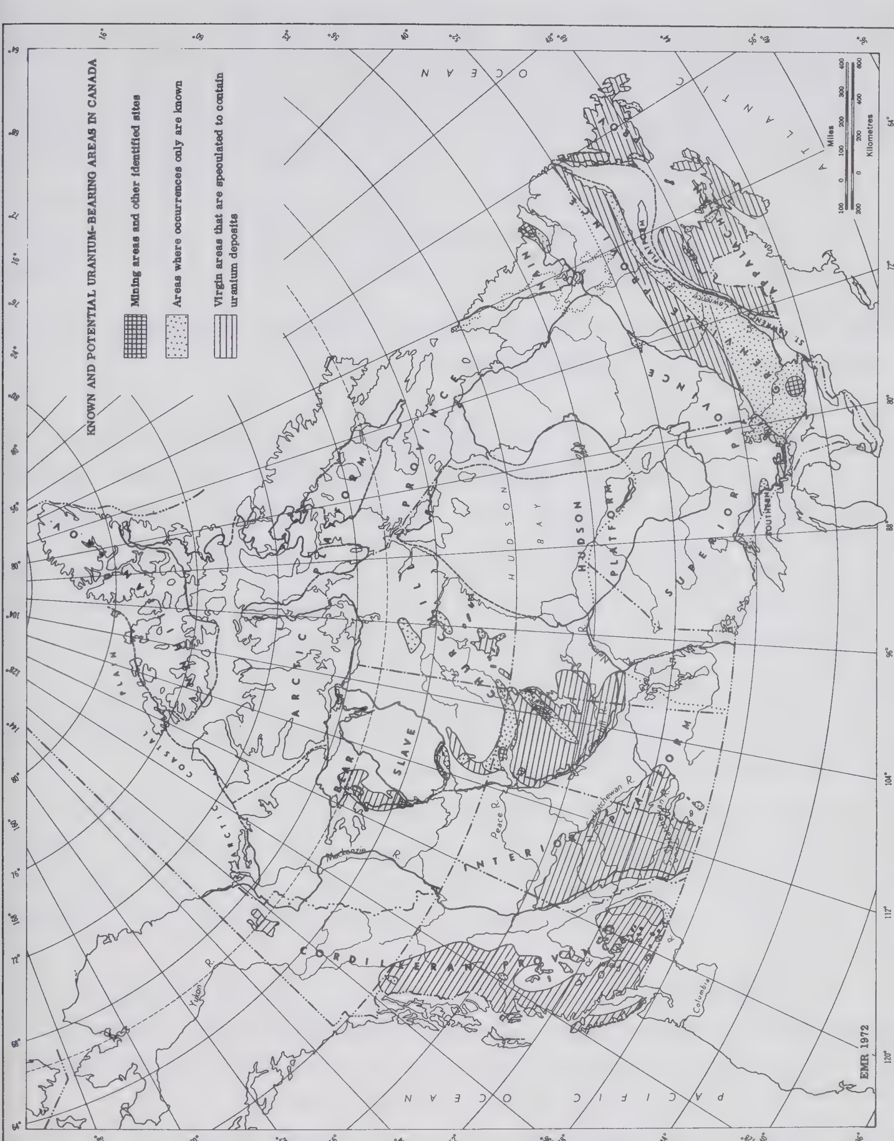
KNOWN AND POTENTIAL URANIUM-BEARING AREAS IN CANADA
Mining areas and other identified sites
Areas where occurrences only are known
Virgin areas that are speculated to contain uranium deposits
ARCTIC COASTAL PLAIN
ARCTIC PLATFORM
CHURCHILL PROVINCE
BEAR
SLAVE
INTERIOR PLATFORM
CORDILLERAN PROVINCE
HUDSON BAY
HUDSON PLATFORM
SUPERIOR PROVINCE
GRENVILLE
APPALACHIAN
ATLANTIC OCEAN
PACIFIC OCEAN
Mackenzie R.
Peace R.
Yukon R.
Columbia
Saskatchewan R.
Nelson R.
Churchill R.
Miles
Kilometres
EMR 1972

Figure 1

the reason that deposits of ore grade are known only in rocks of earliest Proterozoic age. Nevertheless a working committee of experts in the IAEA has recommended that conglomerates of younger ages should be tested for uranium, but the favourability in these cases would be somewhat less.

Because of the tabular nature of these deposits, estimates of reserves are comparatively easy to calculate, and additional resources can be estimated with greater accuracy than with deposits of other types. Furthermore, since low-grade beds are intersected in the search for higher-grade ores, there is an abundance of information on low-grade ores. In addition, research on new methods of mining these low-grade deposits and on methods of extracting the uranium by leaching, give excellent promise that in the Elliot Lake area much uranium that is not now exploitable by conventional methods may be recoverable at considerably lower prices, after the higher-grade ores are mined. It should be noted that quartz-pebble conglomerate ores are found at such depths that only underground mining methods may be used.

Conglomerate ores have contributed 66% of Canadian uranium production, and constitute over 70% of Canadian reserves.

Vein and replacement ores: Uranium-bearing veins are generally narrow, only a few feet wide at best. Replacement deposits are more irregular in shape and may achieve comparatively large dimensions in two or three directions and thus have lower mining costs. Although some deposits are almost entirely vein or replacement, they commonly grade into one another and they have a common genesis. Their locations and sizes are governed chiefly by local structural and chemical features of their host-rocks. Because of this, estimates for vein and replacement deposits are relatively unreliable even where detailed geological maps are available. For areas like Baker Lake, District of Keewatin, where deposits of this type occur but for which only reconnaissance style maps are available, the difficulty of estimating additional resources is formidab'e. Vein and replacement deposits have produced 29% of Canadian uranium.

Pegmatite ores: Pegmatite ores may be subdivided into two types as follows:

a) *Red pegmatites:* Red uraniferous pegmatites consist of irregular, pod-like bodies that, in part at least, show intrusive relationships with the host rocks. Due to their more or less erratic distribution, exploration and mining costs are comparatively high.

b) *White pegmatites* (and associated host rocks). Within widespread metamorphic terranes are metamorphic complexes within which exist, numerous layers and pods of white pegmatite. In places, parts of the host rocks may be somewhat uraniferous. Deposits of this type have never yielded uranium ore.

Sandstone ores (including conglomerate channels). Uranium deposits in sandstone represent about 96% of uranium reserves in the United States and consist of blanket-like and sinuous bodies, and minor conglomerate channel deposits. Sandstone deposits have not been identified in Canada except for one small, low-grade conglomerate channel in southern British Columbia. However, huge areas in most of the country outside the Canadian Shield are to various degrees geologically favourable for such deposits.

Lignitic uranium ores: Uraniferous lignites are, in morphology, somewhat like conglomerate ores. In no country have lignitic ores been very profitable to mine. In Canada uraniferous lignites are known in Cypress Hills of southeastern Alberta and southwestern Saskatchewan. Only very low grade material has been found but the favourable area is very extensive.

Miscellaneous ores and by-product sources: Several other types of uranium deposits have been included in classifications, but none can be said to be more than a minor source of uranium except for uraniferous carbonaceous shale which in Sweden contains huge reserves of very low grade ore. No uraniferous shales of interesting grade are known in Canada.

Chapter 3

ECONOMIC ANALYSIS OF OIL AND GAS RESOURCES

There can be little question that Canada is abundantly endowed with energy resources in purely physical terms and in relation to our own needs. Economically, however, much of this resource may be beyond reach. What, then, is likely to be the cost of developing and delivering these resources to market? Further, how do these costs compare to expected international price levels for similar energy commodities? This section attempts, on the basis of some very preliminary estimates and tentative data, to answer these questions.

Canada currently depends upon petroleum and natural gas for some two-thirds of its primary energy requirements and this situation is expected to continue to the year 2000. The cost at which domestic crude oil and natural gas can be made available is of fundamental importance, therefore, in the consideration of Canada's future energy policy options.

The following discussion deals, in a very general way, with the cost of conventional oil, heavy oil and synthetic (oil sands) oil production from the provinces. No separate economic analysis of these resources was conducted. Frontier oil and gas potential, however, is analysed in detail on the basis of the two sets of Geological Survey resource estimates presented in a foregoing section. Judgements are made as to the distribution of these resources into a range of oil and gas pool sizes and estimates are provided of the full range of expenditures that must be made in order to develop and produce these resources. These costs include all capital and operating expenditures, royalties, income tax and a reasonable return on investment. Graphs and tables of the quantities of oil and gas that might be made available at various wellhead prices are presented.

Transportation charges are then added to the wellhead cost to determine the cost of delivering oil and gas to the points of consumption in southern Canada. Graphs and tables of the quantities of oil and gas that might be delivered at various market price levels are also presented.

The analysis is based on very tentative data and a large degree of uncertainty exists. The limitations of the data used in the analysis and the approach itself are discussed.

The Provinces

Conventional Oil

As indicated in a preceding section, at least 4 billion barrels of conventional oil remains to be found in the provinces, while at least 40 trillion cubic feet of

natural gas is expected. Part of these resources will become available at present prices. A significant amount, however, will only become available as prices increase. This oil and gas will probably be in relatively small pools that are hard to find. Higher prices for oil and gas will allow oil companies to produce oil or gas from smaller and less profitable fields, while it will allow explorers to expand their drilling programs and take higher risks. We estimate that almost all of the estimated provinces oil resources can be discovered and produced for a price of $6 per barrel. A city gate price of $1.25 would bring most of the gas potential to market. In view of the fact that these resources are fairly easily accessible and immediately transportable, they are of great importance to medium term supply considerations. Further studies will therefore be undertaken shortly to determine the relationship between prices and economically recoverable potential.

Alberta Oil Sands

Currently, Alberta oil sands are being mined by open-pit mining techniques. It is generally estimated that present operations will only reach an adequate profit level at somewhat higher oil prices than today. A number of mines are planned at the moment in anticipation of higher energy prices. For prices somewhere between $3.75-$4.50 per barrel, a limited number of open-pit mining projects will become economically attractive. Current prospects are based on mines where the oil sands have a rather high yield per ton and where the oil sands occur at the surface or under thin overburden. As prices increase, it will be possible to mine both deeper and lower quality oil sands. The mining of very deep oil sands below an overburden of 250 feet will pose considerable technical problems and incur higher costs. It is estimated, therefore that oil sands volumes that can be recovered by open-pit mining are limited to about 65 billion barrels. About 35 billion barrels can probably be recovered for a price of about $6 per barrel; the remainder would require higher prices.

It is very likely that in the coming 15 years, methods will be developed that can extract oil from the deeper oil sands with so-called "in-situ" methods. By these processes the oil is separated from the sands beneath the surface, i.e. in place, without the necessity of mining the sands. Various methods are currently being considered. In practice, the operation will be similar to that of a normal oil production operation with the exception that steam injection "fire flooding" or solvent processes will be used to reduce the oil viscosity thus permitting flow to the producing wells. It is yet uncertain what the cost of such operations will be, but it is generally estimated that rather significant volumes of oil can be recovered for prices between $5 and $8 per barrel.

Alberta Heavy Oils

In central eastern Alberta, mainly in the Cold Lake area, important deposits of heavy oil occur that can only be produced economically by in situ methods. It is likely that the production of these heavy oils will be easier than the production of oil-sand oil by in-situ methods. The heavy oils are roughly transitional in physical properties between the oil sands as characterized by the Athabasca deposits and conventional crudes. Although recovery problems are similar in nature, flow

of the heavy oils to the producing wells is easier and less costly to induce. It is likely that significant volumes of this oil can be recovered for prices between $5-$7 per barrel.

FRONTIER OIL AND GAS POTENTIAL

The foregoing section presents estimates of the volumes of oil and gas which may be recoverable from Canada's frontier areas. The figures presented are estimates of physical quantities only and in so far as possible no economic bias has been attached to these numbers. These physical estimates must be examined further in order to attempt to determine the volume of oil and gas that may be economically recoverable under foreseeable cost and price conditions and to further attempt to determine the rates at which these resources may become available.

Methodology

There are undoubtedly numerous ways in which such an analysis could be attempted. Any rigorous analysis, however, should take into account that there are significant economies of scale in oil and gas production and further, must make assumptions as to the guidelines to be used in estimating well productivity. The range of pool sizes and the number of each contained within a basin are critical to an accurate representation of the costs of oil and gas for that basin. The method selected for this analysis assumes that a basin's recoverable oil and gas potential will be contained in a large number of pools which will be log-normally distributed [1, 2, 3, 4] with respect to size, as shown in Figure 1.

The method further makes use of the fact that the above relationship becomes linear when plotted on logarithm-probability paper.[5] Thus the entire curve i.e. the entire frequency distribution of pools within a basin, can be defined from estimates of the mean pool size and the standard deviation (or variance), or from any two points on the line such as the mean and maximum pool size anticipated.

Once the distribution of pool sizes within a basin has been estimated, it is a simple step to determine the distribution of potential reserves by pool size classification within each basin, as shown in Figure 2.

The remaining requirement in estimating a supply curve for both oil and gas for each basin is to derive a correlation between wellhead cost and pool size. Such costs, of course, will vary widely because of differing climatic conditions, transportation and logistical problems, depths of producing horizons, oil and gas quality and well productivity. The EMR has prepared such estimates of eleven separate cost areas on the frontier. Industry sources, consultants and the Depart-

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[1] Kaufman, G. M. Statistical decision and related techniques in oil and gas exploration. Prentice-Hall Inc., Englewood Cliffs, N.J.

[2] McCrossan, R. G. An analysis of size frequency distribution of oil and gas reserves of Western Canada. Institute of Sedimentary and Petroleum Geology, Calgary, Alberta.

[3] Allais, M. Method of appraising economic prospects of mining exploration over large territories. Algerian Sahara Case Study, Management Science, Vol. 3, No. 4, July 1957.

[4] Krige, D. G. A statistical approach to some basin mine valuation problems on the Witwatersrand. *J. Chem. Metall. and Mining Soc. of South Africa*, Vol. 52, No. 6, December 1951.

[5] Cassie, R. M. Some uses of probability paper in the analysis of size frequency distributions. *Austral. J. Marine and Freshwater Research*, Vol. 5, No. 3, Sept. 1954.

ment of Indian and Northern Affairs contributed much of the information that forms the basis for these costs. It should not be inferred however, that these initial results represent the final answer on frontier resource supply. This study merely represents a first attempt. Undoubtedly many changes both in the underlying data base and in the methodology will be necessary in the years to come. For the present purposes however, and in order to produce a single reasonable result (as opposed to a large sensitivity study) wellhead cost curves for various pool sizes have been used which are representative of average conditions within each basin. The configuration of these curves is generally as shown in Figure 3.

Figures 2 and 3 can now be integrated to yield the final wellhead supply curve. These curves, in turn can be used to derive the supply curves for oil and gas delivered to the points of consumption by addition of the appropriate pipeline or tanker transportation tariffs. The final result is as shown in Figure 4.

The individual basin curves are then summed to produce a total Canada supply curve. Comparison with predicted prices enables estimates to be made of the volume of supply that may be available to meet Canadian requirements or export demand.

Comments on Methodology

The analysis makes use of an oil or gas producing pool as the basic unit to which most other estimates are related. The principle of log-normality is used to approximate the size distribution of pools within a basin. It has been shown for many oil and gas producing areas throughout the world that the frequency distribution of pool sizes within a basin approximates a normal distribution curve skewed strongly to the left. Thus if the *logarithm of pool size* is plotted versus frequency, a good approximation of a normal distribution curve results. Hence, the name, log-normal. Knowledge of this principle and its application to Canada's frontier areas allows estimates to be made of the number and size of the oil and gas pools in which the potential oil and gas resources may occur within each basin. The maximum likely pool size within each area is predicted on the basis of geological knowledge of the structures to be encountered, their areal extent and closure. In any basin, only one or two of these maximum pools are likely to be discovered. There may be two or three second order pools, several third order pools, and possibly dozens of smaller pools according to the principle of log-normal distribution.

As with most other oil and gas producing areas of the world most of each frontier basin's reserves will be contained in a few large pools. An industry rule of thumb states that 50% of the reserves will be found in only 5% of the pools and that 90% or more of the reserves will be found in just 50% of the pools. In much of Canada's frontier area with its high development cost or high transportation cost, or both, the smaller or marginal pools will be uneconomic on the basis of foreseeable costs and prices. These smaller pools, therefore, are of little interest both from the point of view of reserves contained and from the point of view of the economic feasibility of their development.

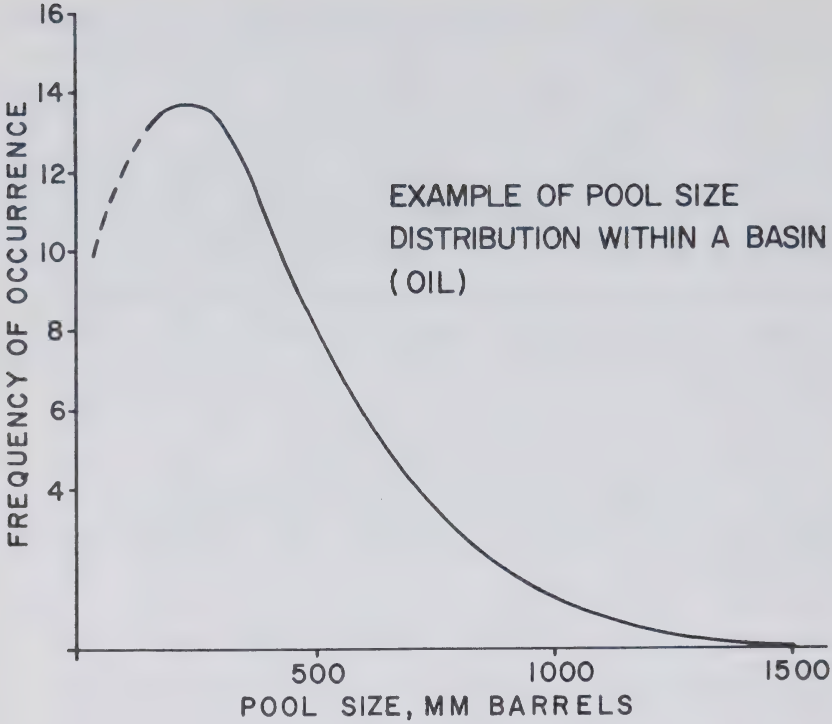


Figure 1

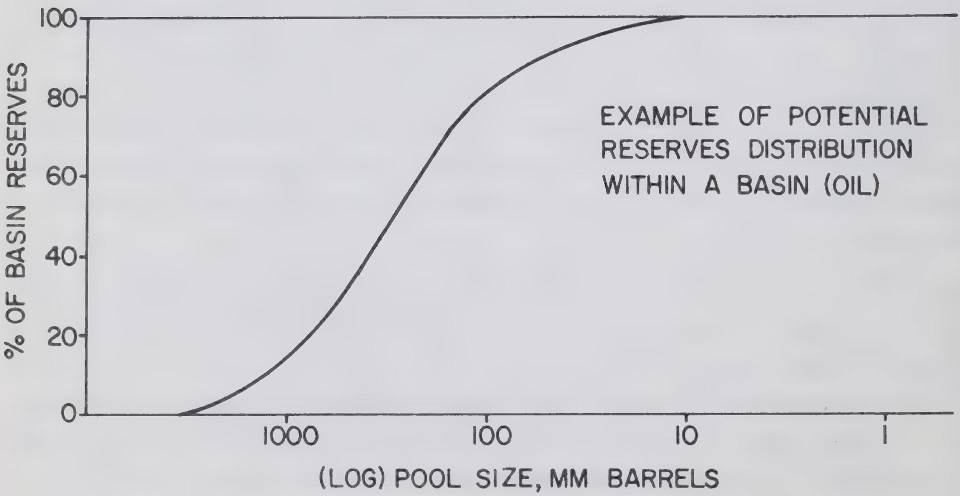


Figure 2

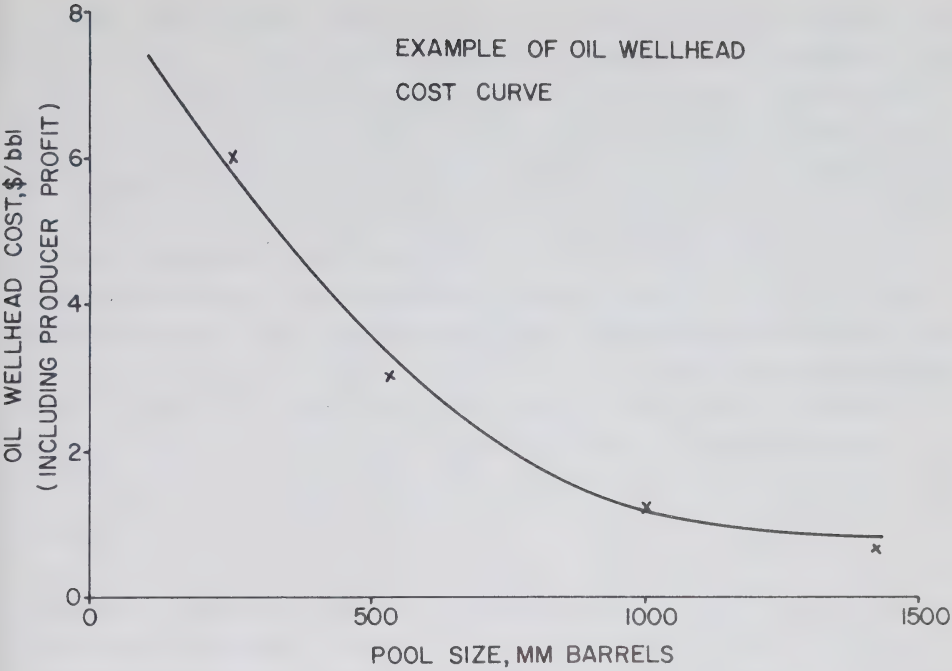


Figure 3

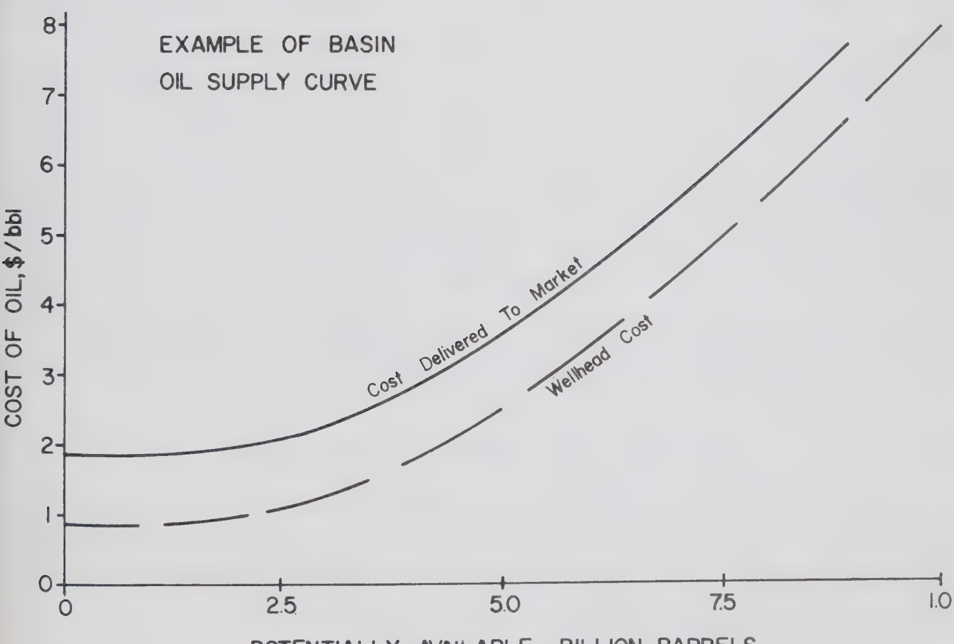


Figure 4

A second key assumption made in preparing the cost estimates is that of well productivity. This is possibly the most important factor entering into the economic analysis and yet the one in which the least information is available and the largest variation can occur. There is little doubt that if well capabilities in the range of 5-10,000 barrels per day as have been encountered in the Prudhoe Bay field or in the North Sea are found in the Mackenzie Delta for example, the economics of oil production there will be highly favourable. On the other hand, production rates in the order of 20-30 barrels per day per well which are sufficient to make for an economically viable operation in Alberta would be simply uneconomic in the Mackenzie Delta where individual well costs in the order of $1 million or more are likely.

For the purposes of this analysis, well productivities have been estimated for each basin taking into consideration the type of reservoir rock to be encountered, its probable permeability, formation thicknesses and anticipated reservoir pressures. It has further been assumed that well productivity will generally be related to pool size i.e. larger pools will have higher productivity wells. There are, of course, many exceptions to such an assumption. However, for a given pool, individual well productivity is directly proportional to formation permeability *and* to the number of feet of reservoir rock open to production within each well bore. Further, it is logical to assume that as pool sizes increase, formation thicknesses will likewise increase. That is to say the larger pool will not only increase in areal extent but will also increase in thickness. Generally speaking, then, the larger pool will produce from a greater oil or gas zone thickness, i.e. more feet of reservoir rock available for production in each wellbore.

The cost estimation procedures used are those generally accepted in the industry. Unit costs of oil and gas are carried through to the point of delivery to markets in Canada's industrial centres. These unit costs include taxes, royalties and profits. The capital and operating cost estimates are based largely upon data submitted to the various government departments, upon consulting reports and figures obtained directly from industry sources. At this stage these costs must be considered to be fairly "rough-cut", particularly for the longer term supply areas where new technology may be required before development can proceed. They are considered to be, however, sufficiently representative to provide a basis upon which a reasonable analysis may proceed.

The Cost of Frontier Oil and Gas

The cost of oil or gas delivered to the point of consumption can, generally speaking, be considered to be the sum of the following major cost components: finding costs; the depreciation of development expenditures; operating expenses; tax and royalty payments; transportation costs.

A brief outline of each of these categories follows:

Finding Costs. Finding cost in this context refers to the total expenditures required to discover a single oil or gas pool. The approach chosen here has been

to assume an exploratory drilling success ratio to determine the number of wells required to discover a pool. The costs of these wells and the cost of all the prerequisite exploration work are estimated for each basin area. Thus, the cost of exploration activity in the form of surface geology, magnetic or aeromagnetic surveys, geophysical investigations, core-drilling, etc. is added to the exploratory drilling costs to determine the overall expenditure required to discover a pool.

For example, in the Sverdrup Basin, a success ratio of one pool discovery for every eight exploratory wells may be a reasonable assumption in the initial stages of exploration. The cost of all associated geological and geophysical investigation (G&G) may be in the order of $1,000,000 per exploratory well location while the cost of drilling the eight exploratory wells at (say) $2,000,000 per well totals $16 million. The total finding cost *per pool* would thus be $24 million. If this exploration expenditure discovers a pool of 5 trillion cubic feet (Tcf), the unit finding cost is, therefore, 0.5¢ per Mcf. If, on the other hand, an oil pool of 500 million barrels were discovered, the unit finding cost would be 5¢ per barrel.

For most of the important sedimentary basins of Canada, at least some exploration and cost history is available so that the magnitude of these costs can be estimated with reasonable accuracy. Particularly in the initial stages, exploration is aimed at discovering those large pools that contain the bulk of a basins reserves. For this reason, errors in the estimation of finding costs and success ratios have little impact on the overall cost of oil and gas delivered to market from these large pools.

The example finding costs noted above may appear to be miniscule in relation to the final delivered cost of the oil or gas. The exploratory expenditure, however, is "front end" high risk investment and represents the driving force behind the entire oil and gas production cycle. In addition, if a substantial delay is involved between discovery and initial market deliveries, these expenditures may compound to more significant proportions. In the long run, they cannot be treated as sunk costs by a company basing its decisions on full-cycle rates of return.

As time goes by, two countervailing factors will affect finding costs. Firstly, as an area is explored, more and more information is accumulated and assimilated by the oil companies, thus leading to better success in exploration. Offsetting this "learning curve" factor, however, is the fact that as more and more of the large pools are discovered, the companies are, of necessity, searching for an ever-decreasing inventory of economically drillable prospects. Normally, there is a threshold level of several or several dozen wells required before the companies find the "exploration keys" that provide the analytical tools by which large pools can be discovered. As these keys are uncovered, very high localized success ratios may result and a large bulk of a basins reserves may be uncovered in a very short period of time. Even after the major plays have been virtually exhausted, however, companies will continue to drill in the hopes of discovering strati-

graphic type reservoirs or smaller, but prolific pools located in close proximity to the pipeline infrastructure. (Stratigraphic reservoirs are quite difficult to find and are often found by accident, since they do not require the presence of a structural anomaly in the geological formations and are, therefore, not normally detectable by the standard geophysical investigation.) Even during this mature phase of the exploration cycle, success ratios may be fairly high, but the reserves discovered per exploration well, per foot drilled, or per dollar of exploration expenditure may be low.

Production Forecasts. In order to calculate the wellhead cost of oil or gas, a production forecast for each pool must be made. A pool's peak producing rate determines the number of wells that must be drilled and governs also the design and cost of production facilities and pipelines. The lead time required before peak rate production is achieved, the period during which peak production rates can be maintained and the rate of decline of production thereafter can greatly affect the present worth of production revenue, thus influencing the wellhead cost.

For the oil forecasts, lag time varying between 2 and 5 years between the time of discovery and initial production are assumed. This is followed by a two year build up to a peak production rate of 7.3%/year of initial recoverable oil reserves and lasting for a period of 7 years. Production declines thereafter at a rate of 15% per year to the economic limit. This schedule provides for production of approximately 96% of recoverable oil over a period of 23 years.

The natural gas production forecast for each pool assumes that a peak rate of one million cubic feet per day (MMcfd) for each 8 billion cubic feet (Bcf) of recoverable pipeline gas reserves is achieved in the first year of production and is maintained for a period of 15 years. Following the end of the level production period decreasing deliverability causes a production decline of about 15% per year. Approximately 87% of the recoverable pipeline gas is produced by the end of the 23rd year. Similar lag periods between the discovery date and the date of initial production are assumed for gas pools.

Development Expenditures. The estimation of capital expenditures for the development of the hypothetical oil and gas pools is necessarily approximate because the location of the discoveries, well productivity, well depths, oil and gas quality, and many other factors are unknown at this time. An attempt has been made, however, to prepare an engineering type estimate of the cost of all facilities necessary to produce, process and convey to a main trunkline the oil or gas predicted to be found in each of the pools. Cost estimates are intended to be representative for an entire basin area and are based as much as possible upon historic well drilling costs in that area or similar areas or upon documented cost histories of areas of similar logistic, climatic and geological characteristics. In some areas, such as the Hudson Bay, the Labrador Shelf, or the Arctic Islands offshore areas, little hard information is available and the estimates used represent the collective thinking of industry representatives and consultants. In other areas, like the Grand Banks, or the Nova Scotia Shelf, costs can be inferred from the cost of drilling exploration wells to date and costs encountered in similar developments in other areas of the world, notably the North Sea.

An example of the magnitude and breakdown of these capital investment estimates follows.

EXAMPLE OF DEVELOPMENT COST ESTIMATES

	Mackenzie Delta Onshore	Scotian Shelf Offshore
	1,000 mm bbl pool	500 mm bbl pool
Development Costs, $mm		
Wells—productive, injection and dry	120	105
Production facilities (incl. pads and platforms)	72	73
Pipeline (except mainlines) and storage	23	5[1]
Camp and offsites	10	—[2]
Total initial investment	$225	$183
Unit cost, cents/bbl	23	37
Pool peak production rate, MB/D	200	100

[1]Pipeline to shore not included.
[2]Yard and dock facilities included in cost of platforms.

These numbers appear reasonable by present North American standards. The cost per unit of production for development drilling and producing facilities for the period 1967-1971 averaged 23¢ per barrel in Western Canada and 48¢ per barrel in the United States. These historic costs, of course, are largely a reflection of the low well productivity in each of these areas.

By way of comparison, in the prolific fields of the Middle East, depreciation (i.e. development expenditure writeoff) might average in the range of 5-10¢ per barrel while a major offshore pool in the Beaufort Sea could be 50-100¢ per barrel or higher.

As previously pointed out, these costs are a very sensitive function of well productivity. The costs of the wells themselves, may constitute somewhere in the order of 50-60% of the total development cost. Also, if fewer wells are required, fewer pads or platforms will also be required. These structures, required in tundra and offshore areas respectively, also constitute a principle cost component. Thus, the assumption of well productivity has a pervasive influence on the cost of oil or gas at the wellhead. Attempts to refine cost estimates generally result in a sensitivity analysis of the effect of well productivity on wellhead cost.

Operating Expenses. The operating expense component includes such items as operating personnel salaries, repairs and maintenance, parts and supplies, well servicing and workover costs, transportation costs of personnel and materials, processing costs, camp and offsite expenses and administration and overhead. Estimates have been made of operating expenses that can be reasonably expected for each of the pool size estimates.

Generally speaking, the magnitude of the operating expenses, is a function of the size and cost of facilities installed in the field so that costly field facilities usually lead to high operating expenses. A rule of thumb sometimes applied is that operating expenses or lifting costs are roughly equal to the depreciation of drilling

and production facilities costs, both on a unit of production basis. There is often a trade off, however, between a high degree of automation which leads to high capital costs and generally low expenses and a system employing mainly manual operation which may require less investment, but incurs a higher operating expense.

Income Tax, Royalty and Net Profit. Depletion allowance in Canada is 33⅓% of taxable production income provided that the company has "earned" its depletion, i.e. its total eligible exploration expenditures equal or exceed three times the depletion claimed. Assuming depletion is earned therefore, a corporate income tax rate of 50% results in an *effective tax rate* in the producing segment of 33⅓% (i.e. 50% of 66⅔%).

Net profit after tax was determined assuming that a 20% discounted cash flow rate of return (DCF) represents a reasonable return on capital sufficient to reward the high exploration risks undertaken and sufficient, also, to maintain a viable and active domestic exploration activity. This profit figure is, of course, net after payment of all costs, royalties and income taxes.

Royalty payments were determined by applying current effective royalty rates of 5% or 10% against field or wellhead netback values.

Wellhead Cost Supply Curves

The wellhead cost curves which follow are typical examples of the application of the foregoing methodology. Typically, basins contain approximately one-half or one-third of their reserves in a relatively low cost range because of the discovery of large pools with their attendant low cost reserves. As pool size (and incidentally well productivity, according to the assumptions) decreases, costs increase. Thus, the final 20-25% of a basins reserves may be in the very high cost range in relation to the reserves contained in the largest pools. The Sverdrup Basin onshore gas curve, Figure 5, is typical of a large potential reserve, relatively low wellhead cost basin. Note that wellhead cost is plotted versus cumulative potential pipeline gas available at wellhead cost. Approximately one-half of the onshore gas potential of the Sverdrup Basin is estimated as eventually becoming available at 30-36¢ per Mcf wellhead price. Similarly, it would require a wellhead price in the order of $1.00 per Mcf to bring forth potential resources in the order of 100 trillion cubic feet, that is about 85% of the recoverable pipeline gas for the basin.

Another example is the Beaufort-Mackenzie onshore oil curve, Figure 6, which is typical of a fairly small potential, limited area, prospective oil basin. The curve indicates that approximately *one-third* of the basins 3.5 billion barrels of recoverable oil potential may become available at $3.00 per barrel wellhead price. From the configuration of the curve, one might conclude that there is only one major oil pool accumulation in the basin. This leads to a fairly low cost at the initiation point of the curve. As pool size decreases, costs increase rather rapidly so that much of the basin's oil requires very high wellhead price of $10.00 per barrel. If reasonably foreseeable wellhead prices peak out at a level of $5.00 per barrel, we might anticipate that only about 1.7 billion barrels or approximately one-half of the recoverable oil potential in the Beaufort-Mackenzie onshore basin would be developed. Once again, it must be emphasized that these estimates are highly sensitive to well productivity and pool size assumptions.

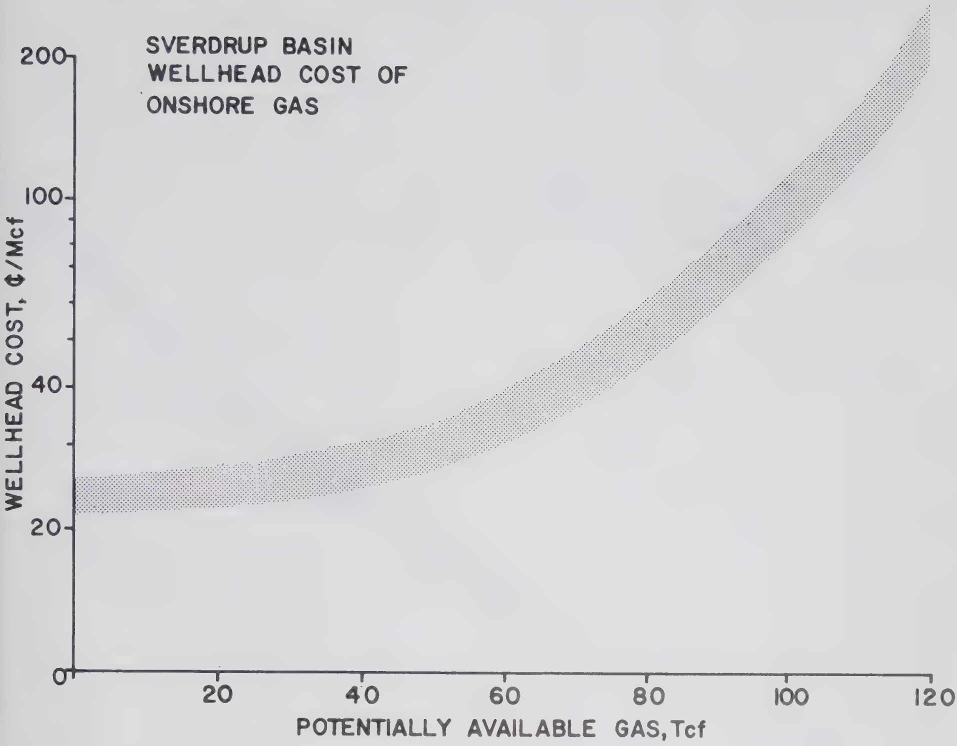


Figure 5

Figures 7 and 8 are the combined total Canada frontier wellhead supply curves for oil and gas. In each case, two sets of curves are shown; those based on the 1972 potential estimates and those based on the 1973 potential estimates. Note that while the difference in estimated oil resource potential was approximately 28%, (i.e. 111 billion barrels of frontier oil in 1972 compared to approximately 80 billion barrels of frontier oil in 1973), the amount of oil that might be recovered at a reasonable maximum wellhead price of (say) $6.00 per barrel, has decreased from about 62 billion barrels for the 1972 estimates to about 33 billion barrels for the 1973 estimates or a decrease of 47%. This is due in part to a significant reduction in the number of very large pools expected to be discovered thus implying that more of the oil is contained in smaller pools at higher cost levels.

Figure 8 shows our estimates of the wellhead cost of gas supply from potential frontier resources for Estimates I (1972) and II (1973). The curves are similar in configuration and magnitude. Each has a significant cost plateau in the range of 50-60¢/Mcf. The curve based on Estimate II shows greater volumes of relatively low-cost gas (30-50¢/Mcf) mainly due to large increases

over Estimate I for the ultimate potential gas resource of the Sverdrup Basin onshore area. At a cost of about 57¢/Mcf the curves are coincident and indicate that about 210 Tcf of potential gas could become available at this wellhead cost.

Tables 2, 3, 4, and 5 included at the conclusion of this section present the data upon which the foregoing curves are based.

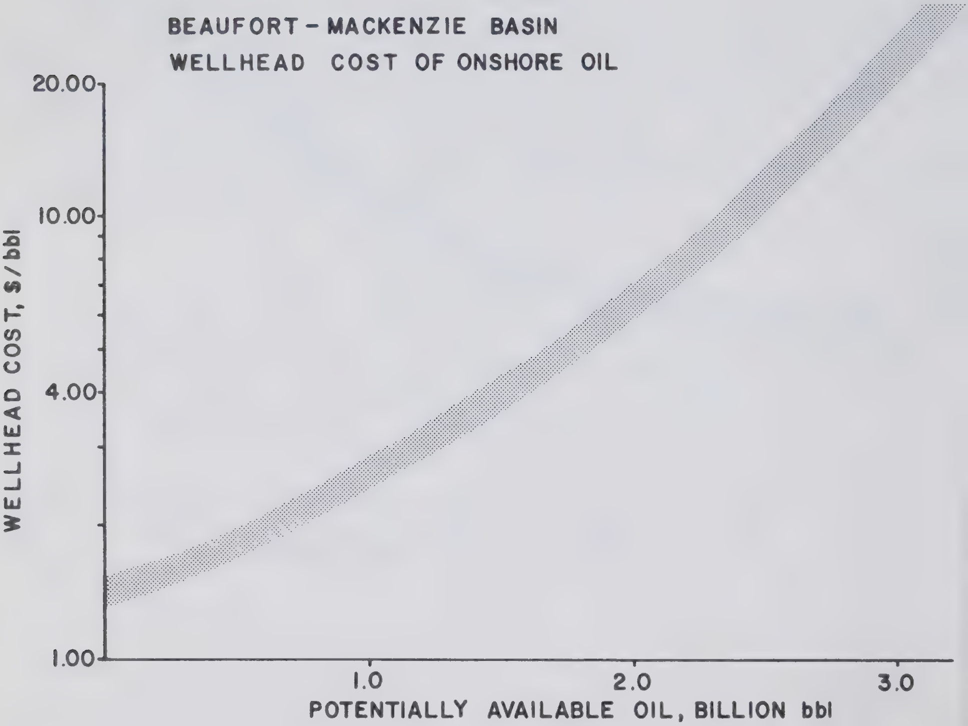


Figure 6

The most significant conclusion that can be drawn from these tables and curves is that surprisingly little of Canada's large oil and gas potential is expected to be available at low wellhead costs. A *wellhead price* of $5.00 per barrel could provide the economic incentive to develop between one-third and one-half of our oil potential. (The cost levels indicated are expressed in constant 1972 dollars.) If this price level were reached in 1982, for example, it would be equivalent to a (then) current price in the order of $7.00 per barrel if the present rate of inflation continues.

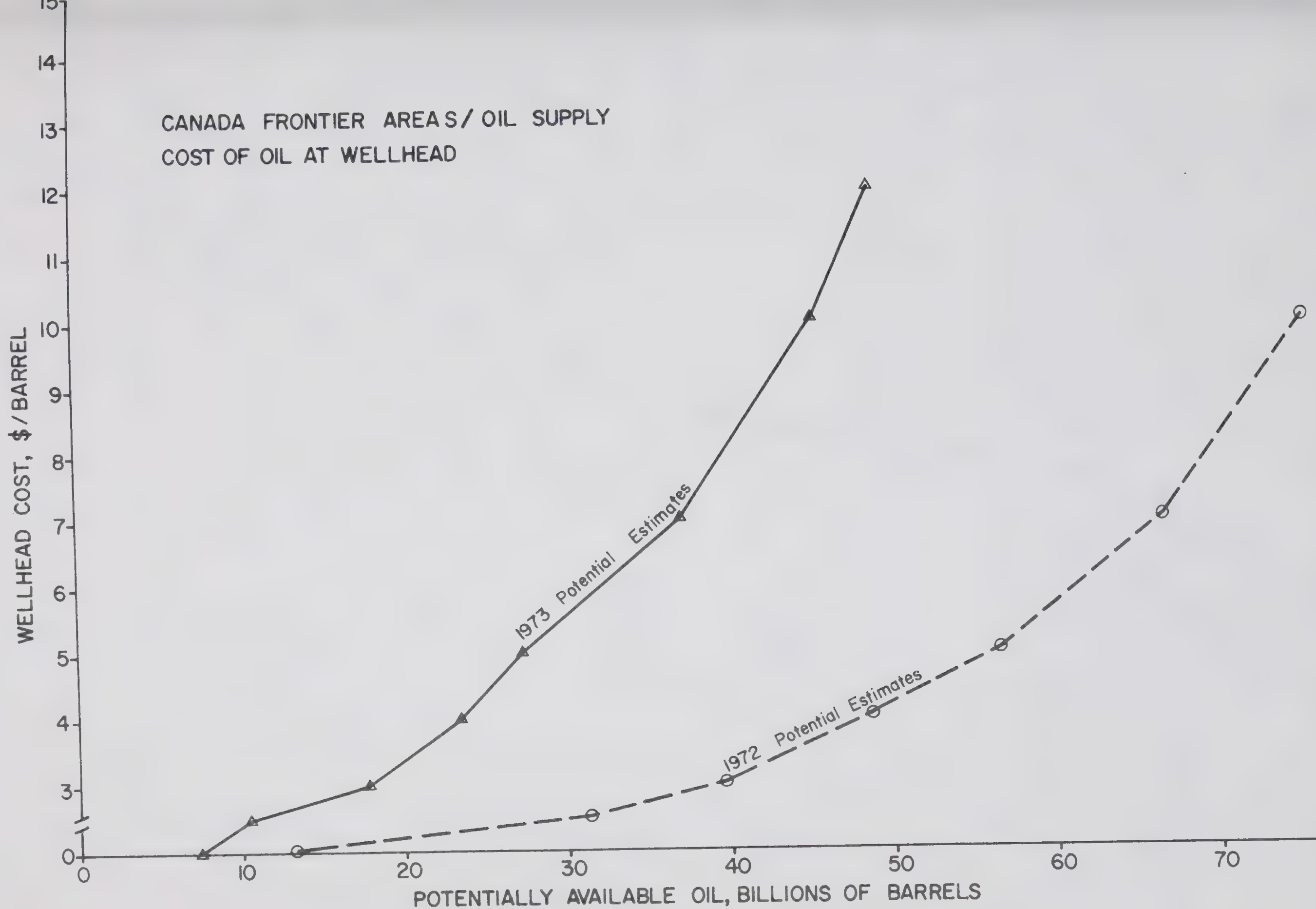

CANADA FRONTIER AREAS/OIL SUPPLY
COST OF OIL AT WELLHEAD
WELLHEAD COST, $/BARREL
1973 Potential Estimates
1972 Potential Estimates
POTENTIALLY AVAILABLE OIL, BILLIONS OF BARRELS
0
10
20
30
40
50
60
70
3
4
5
6
7
8
9
10
11
12
13
14
15

Figure 7

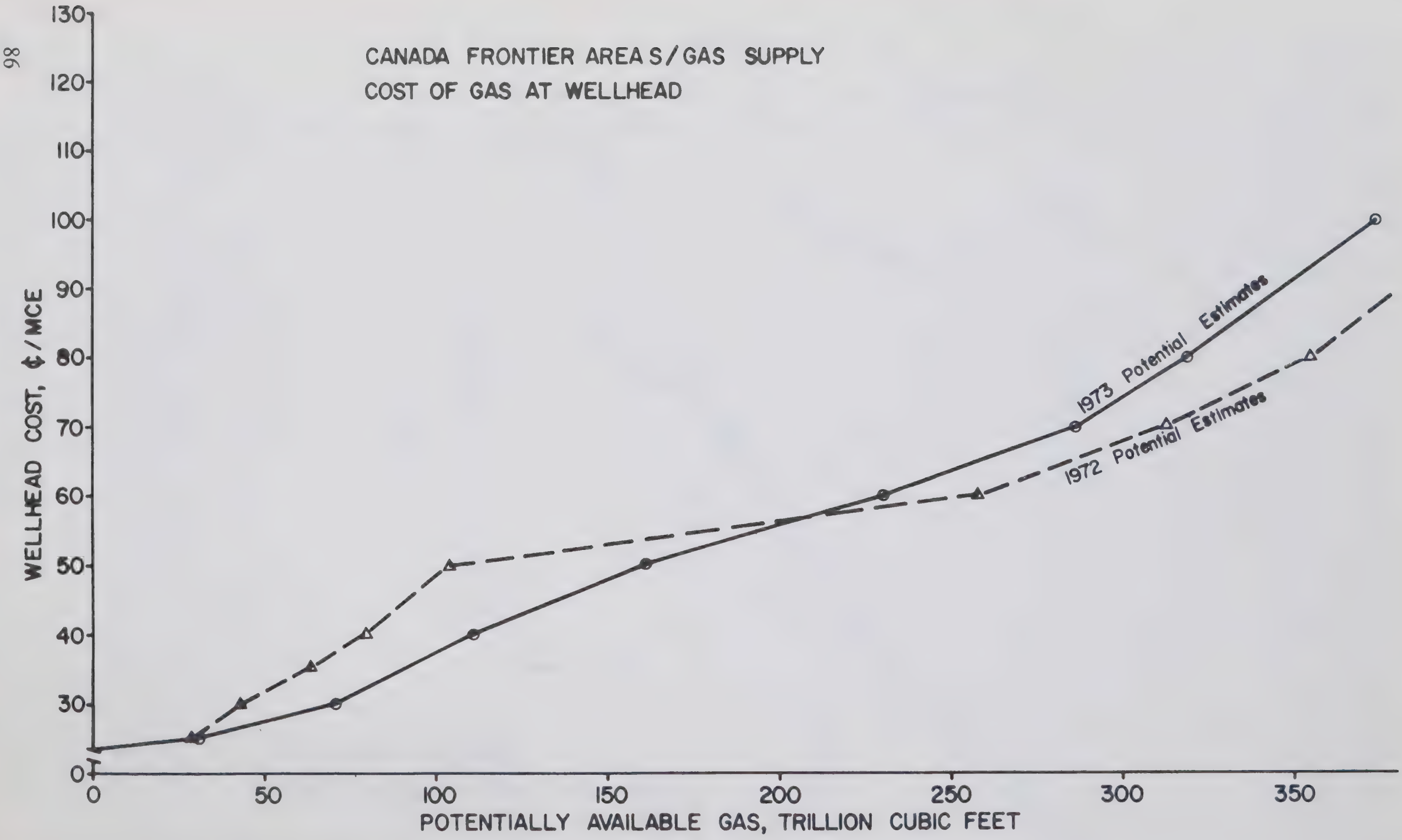

CANADA FRONTIER AREAS/GAS SUPPLY
COST OF GAS AT WELLHEAD
WELLHEAD COST, ¢/MCF
130
120
110
100
90
80
70
60
50
40
30
0
0
50
100
150
200
250
300
350
POTENTIALLY AVAILABLE GAS, TRILLION CUBIC FEET
1973 Potential Estimates
1972 Potential Estimates

Figure 8

Much of our resources will be found in very hostile environments such as the continental shelfs and slopes and in the high Arctic. Technology no doubt will be developed to produce these hydrocarbons but it is doubtful if large volumes of low cost oil or gas will become available.

Economically Developable Potential

In order to determine the fraction of potential resources, that might become available to supplement the Canadian supply, the cost of transportation of frontier oil and gas to the points of consumption must be added to the wellhead costs. The delivered cost then can be compared with long term forecasts of oil and gas selling prices in southern Canada and the United States export market. Estimates of future oil and gas pipeline tariffs from the various basin areas to the lower Canadian mainland i.e. the Great Lakes, are shown in Table 1.

TABLE 1

ESTIMATED FRONTIER OIL AND GAS TRANSPORT TARIFFS
(Using 1973 Area Breakdown)

	Oil Transport Tariff $/Bbl	Gas Transport Tariff $/Bbl
Northern Canada		
Sverdrup Basin Onshore	0.75 & 1.25[1]	0.95
Offshore	0.85 & 1.35[1]	1.00
Arctic Fold Belt Onshore	0.75 & 1.25[1]	1.00
Offshore	1.15	1.05
Arctic Stable Platform Onshore	1.00	1.00
Offshore	1.10	1.05
Arctic Coastal Plain	1.35	1.05
Beaufort-Mackenzie Onshore	1.00	0.75
Offshore	1.10	0.90
N.W.T. Mainland	0.70	0.60
Eastern Canada		
Scotian Basin Attainable	0	0.35
Unattainable	0	0.40
Avalon Uplift Attainable	0.25	0.60
Unattainable	0.25	0.65
East Newfoundland Attainable	0.25	0.60
Unattainable	0.25	0.65
Labrador Shelf and Slope	0.50	0.60
Baffin Island, Atlantic Slope	0.75	0.75
St. Lawrence Platform & Maritime Basin	0	0.15
Hudson Platform	0.75	0.35
West coast		
West coast Offshore	0	0.35

[1]A portion of this oil assumed to be shipped by tanker; the first listed number is for this tanker transport, the latter for pipeline transport.

CANADA FRONTIER AREAS GAS SUPPLY
PRICES DELIVERED GREAT LAKES AREA

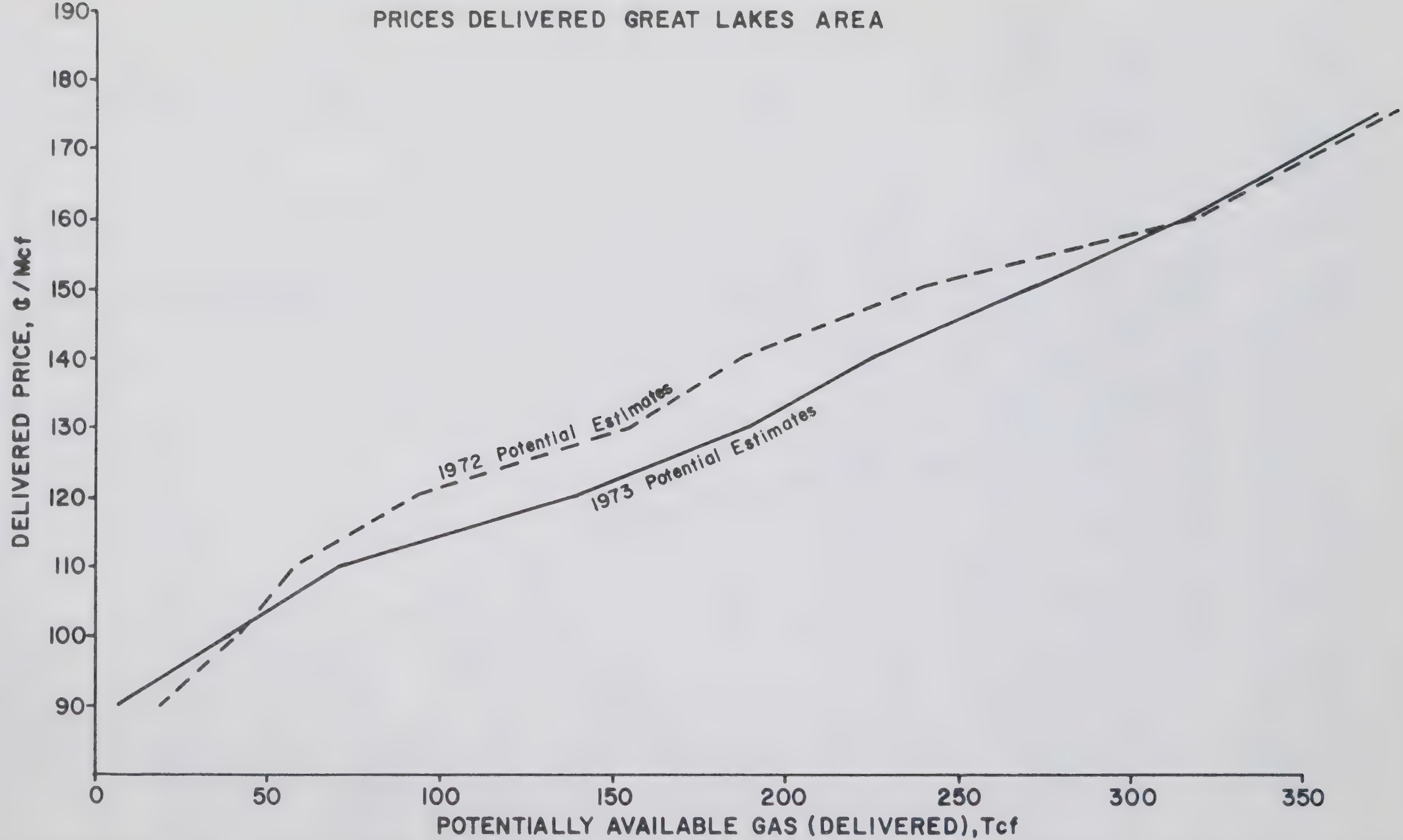


Figure 9

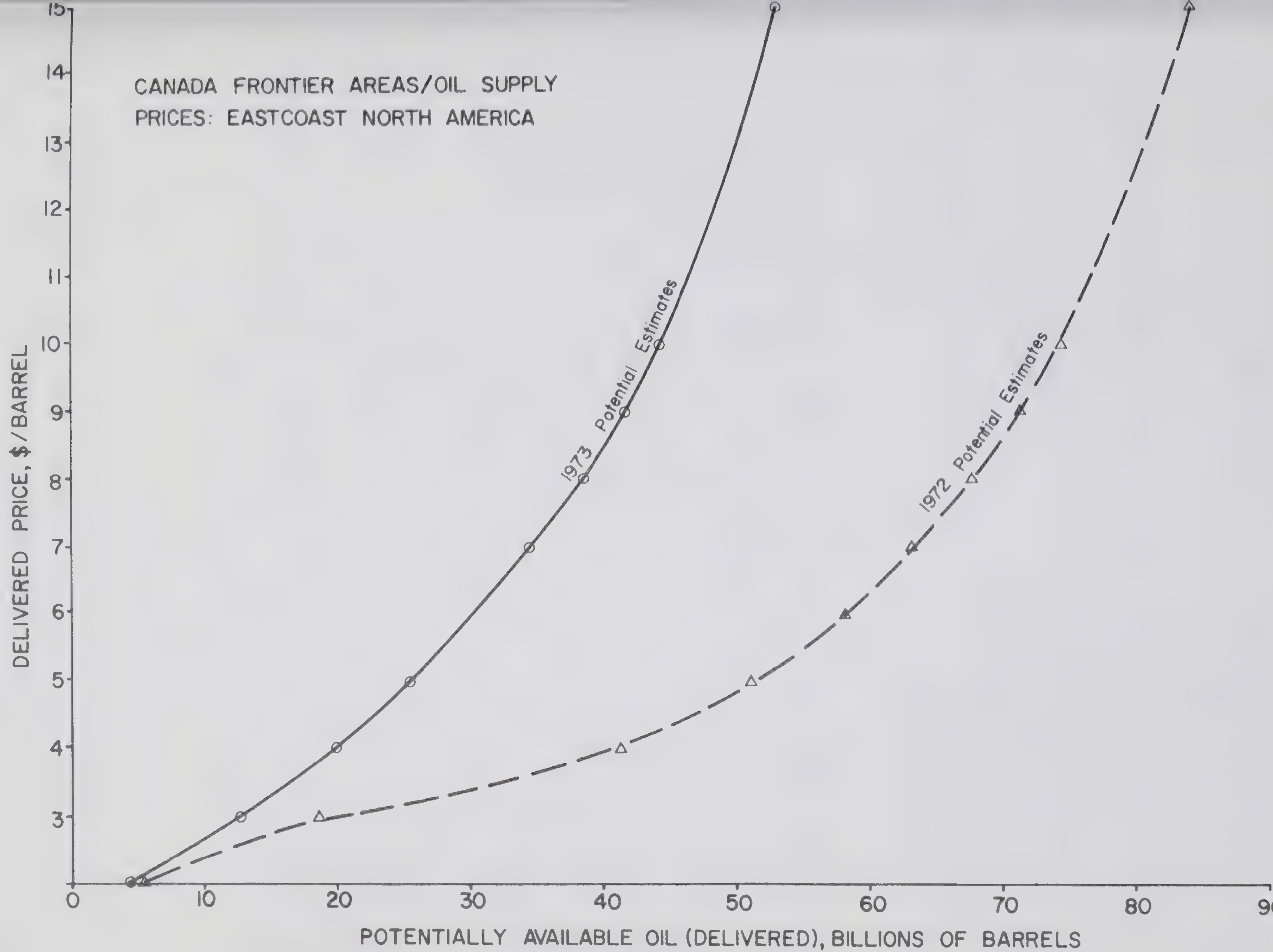

CANADA FRONTIER AREAS/OIL SUPPLY
PRICES: EASTCOAST NORTH AMERICA
DELIVERED PRICE, $/BARREL
POTENTIALLY AVAILABLE OIL (DELIVERED), BILLIONS OF BARRELS
1973 Potential Estimates
1972 Potential Estimates
0
10
20
30
40
50
60
70
80
90
3
4
5
6
7
8
9
10
11
12
13
14
15

Figure 10

Figures 9 and 10 and Tables 6, 7, 8, and 9 show our estimates of the cost of frontier potential oil and gas delivered to points of consumption in Canada. The illustrations show that about 50 billion barrels of oil could be delivered at $5.00 per barrel based on GSC Estimate I (1972) while only about 25 billion barrels would be forthcoming at that price using GSC Estimate II (1973). As the tables show, this is mainly due to a sizeable reduction in the estimates of cheaper northern oil.

Using Estimate I, a potential volume of about 120 Tcf might be economically delivered to southern Canada at $1.25 per Mcf. This is in fairly reasonable agreement with the 155 Tcf resulting from Estimate II.

In order for these volumes to become available, prices of course must develop within a reasonable time frame. But more important, the oil industry must continue to explore and indeed expand their activities on the frontier.

Finally, the industry must be successful in finding the resources of which, thus far, only a trace has been uncovered.

Concluding Remarks

The estimates presented herein are, of course, highly tentative. They are founded upon a series of hypotheses which represent but one of a broad range of outcomes.

As shown by the rather significant change in total Canadian oil and gas potential estimates made by the GSC in 1972 and 1973, the information or data base for the large frontier areas is quite meagre and changes in resource estimates must be expected as new information becomes available as a result of government and industry activity. The assumptions regarding pool sizes and well productivity while reasonable, are based on meagre amounts of data in some areas; "guesstimates" in others. The final element, the cost estimates are intended to be representative of broad regions having a variety of climatic, environmental and logistic conditions. Considerable more input from industry sources would be required, however, before they would justify a high degree of confidence.

Each of these areas will be the subject of continuing study. A computer simulation model designed to determine the probability of various outcomes is being prepared that incorporates probability estimates for each of the input variables. Such a sensitivity analysis will serve to better define the range of results that might be anticipated. As more and better cost and resource information is accumulated, it will be included in the data base. Hopefully, industry sources will continue to lend valuable assistance in these areas.

TABLF 2

CANADA FRONTIER AREAS—COMPOSITE OIL SUPPLY CURVE
(1972 Potential Estimates)

	Potential Oil Available at Wellhead Price, Billions of Barrels													Total
	$1.00	$1.50	$2.00	$2.50	$3.00	$4.00	$5.00	$7.00	$10.00	$12.00	$15.00	$20.00	Re-mainder	Basin Potential
Mackenzie S. of 65°	0.1	0.3	0.5	0.7	9.9	1.0	1.1	1.2	1.3	1.4	1.4	1.4	0	1.4
Mackenzie N. of 65°	1.9	3.6	4.4	4.9	5.1	5.5	5.7	5.9	6.2	5.3	6.4	6.5	0.9	7.4
Sverdrup Basin Onshore	2.6	4.9	6.1	7.0	7.6	8.3	8.7	9.1	9.6	9.7	9.9	10.2	0.7	10.9
Arctic Lowlands Onshore	0	0	0.6	0.9	1.3	2.2	2.8	3.9	4.8	5.1	5.4	5.8	0.9	6.7
Beaufort Sea and Arctic Offshore	0	0	0	11.2	14.3	17.1	20.8	24.7	27.3	29.8	31.6	33.5	10.3	43.8
Scotian Shelf Offshore	0	0	0.4	0.6	0.8	1.4	2.0	2.9	3.8	4.2	4.6	5.1	0.70	5.8
Grand Banks Offshore	0.4	1.4	2.0	2.5	2.9	3.4	3.7	4.2	4.5	4.7	4.8	5.0	0	5.0
Labrador Shelf Offshore	0	0	0	0.3	0.6	0.9	1.1	1.4	1.7	1.9	2.0	2.2	0.9	3.1
Hudson Bay and Foxe Basin	0	0	0	0	0	0.2	0.2	0.3	0.5	0.6	0.7	0.9	0.6	1.5
West Coast Offshore	0	0	0	0	0.2	0.3	0.4	0.6	0.8	0.9	0.9	1.0	0.2	1.2
Labrador and Atlantic Slope and Baffin Basin	0	0	0	3.2	6.0	8.5	10.0	12.3	14.5	15.5	16.7	18.0	6.6	24.6
Total	5.0	10.2	14.0	31.3	39.7	48.8	56.5	66.5	75.0	80.1	84.4	89.6	21.8	111.4

TABLE 3

CANADA FRONTIER AREAS—COMPOSITE OIL SUPPLY CURVE

(1973 Potential Estimates)

	Potential Oil Available At Wellhead Price, Billions of Barrels											Re-	Total Basin
	$1.50	$2.00	$2.50	$3.00	$4.00	$5.00	$7.00	$10.00	$12.00	$15.00	$20.00	mainder	Potential
Sverdrup Onshore	—	1.0	1.7	2.3	3.0	3.5	4.2	5.0	5.4	5.8	6.2	1.0	7.2
Offshore	—	—	—	—	—	—	0.9	1.5	1.8	2.1	2.5	2.2	4.7
Arctic Fold Belt Onshore	—	0.5	0.8	1.1	1.4	1.7	2.1	2.3	2.4	2.5	2.5	0.1	2.6
Offshore	—	—	—	—	—	—	—	—	—	0	0.2	0.9	1.1
Arctic Stable Platform Onshore	—	—	—	0	0.1	0.2	0.4	0.5	0.5	0.6	0.6	0	0.6
Offshore	—	—	—	—	—	—	—	—	—	0	0.1	0.5	0.6
Arctic Coastal Plain Offshore	—	—	—	—	—	0	0.7	1.1	1.3	1.5	1.8	1.7	3.5
Beaufort-Mackenzie Onshore	0.3	0.7	1.0	1.2	1.5	1.7	2.1	2.4	2.6	2.7	3.0	.5	3.5
Offshore	—	—	—	—	—	0	0.5	0.8	0.9	1.1	1.4	1.3	2.7
N.W.T. Mainland	0.2	0.4	0.6	0.8	1.0	1.1	1.3	1.5	1.5	1.6	1.7	0	1.7
West Coast Offshore	—	—	—	—	0	0.1	0.2	0.3	0.4	0.4	0.5	0.1	0.6
Scotian Basin Shelf	0.4	0.6	0.9	1.2	1.5	1.8	2.1	2.5	2.6	2.8	3.0	0.7	3.7
Slope	—	—	—	—	—	—	1.1	1.8	2.0	2.4	2.9	2.6	5.5
Avalon Uplift Shelf	—	—	—	—	0.1	0.1	0.2	0.3	0.3	0.3	0.3	0	0.3
Slope	—	—	—	—	—	—	—	0.2	0.3	0.5	0.7	1.6	2.3
East Newfoundland Shelf	3.0	4.4	5.6	6.3	7.7	8.3	9.2	9.9	10.0	10.2	10.2	0	10.2
Slope	—	—	—	—	—	0	0.9	1.5	1.8	2.1	2.5	2.8	5.3
Labrador Shelf and Slope	—	—	0	0.8	1.4	1.8	2.3	2.9	3.2	3.6	4.0	1.5	5.5
Baffin Island Shelf and Slope and Atlantic Rise	—	0	0	4.0	5.4	6.4	7.6	9.0	9.6	10.3	11.2	3.5	14.7
Hudson Platform	—	—	—	—	—	—	0.3	0.6	0.9	1.3	1.5	0	1.5
St. Lawrence Platform and Maritime Basins	—	—	—	—	0.4	0.6	0.8	1.0	1.1	1.2	1.3	0.2	1.5
Total Canada Frontier Areas	3.9	7.6	10.6	17.7	23.5	27.3	36.9	45.1	48.6	53.0	58.1	21.2	79.3

TABLE 4

CANADA FRONTIER AREAS—COMPOSITE GAS SUPPLY CURVE

(1972 Potential Estimates)

Area	Potential Gas Available at Wellhead Price, Trillions of Cubic Feet												Total Basin Potential
	25¢/ Mcf	30¢/ Mcf	35¢/ Mcf	40¢/ Mcf	50¢/ Mcf	60¢/ Mcf	70¢/ Mcf	80¢/ Mcf	100¢/ Mcf	125¢/ Mcf	150¢/ Mcf	200¢/ Mcf	
Mackenzie S. of 65°	0.6	1.3	2.0	2.8	4.2	5.6	6.6	7.4	8.4	9.1	9.6	10.2	10.8
Mackenzie N. of 65°	10.6	17.0	21.3	24.5	29.0	31.8	34.0	35.5	37.8	39.4	40.6	42.3	47.6
Sverdrup Basin Onshore	17.6	24.7	30.2	34.7	41.6	46.5	50.0	52.8	56.8	60.0	62.0	64.0	65.3
Arctic Lowlands Onshore, Platform	0	0	0	2.5	5.3	8.3	11.5	14.6	20.7	26.0	29.6	34.0	40.0
Beaufort Sea and Arctic Offshore	0	0	0	0	0	92.0	116.0	135.0	163.0	188.0	207.0	232.0	318.7
Scotian Shelf Offshore	0	0	0	3.0	7.7	11.1	13.7	15.8	19.0	21.6	23.4	25.6	33.9
Grand Banks Offshore	0	0	10.0	11.9	14.7	17.0	18.8	20.0	22.2	23.8	25.0	26.3	30.0
Labrador Shelf Offshore	0	0	0	0	0	3.6	3.2	6.4	8.2	9.9	11.2	13.0	18.3
Hudson Bay and Foxe Basin	0	0	0	0	0	0	0	0	1.0	2.0	2.7	3.8	8.7
East Coast Offshore	0	0	0	0	1.6	2.3	2.9	3.3	4.0	4.5	4.9	5.4	7.2
Labrador and Atlantic Slope and Baffin Bay	0	0	0	0	0	40.0	54.0	64.0	75.0	85.0	93.0	104.0	147.4
Total	28.8	43.0	63.5	79.4	104.1	258.2	312.7	354.8	416.1	469.3	509.0	560.6	727.9

TABLE 5

CANADA FRONTIER AREAS—COMPOSITE GAS SUPPLY CURVE

(1973 Potential Gas Estimates)

	Potential Gas Available at Wellhead Price, Trillions of Cubic Feet												
	25¢/ Mcf	30¢/ Mcf	40¢/ Mcf	50¢/ Mcf	60¢/ Mcf	70¢/ Mcf	80¢/ Mcf	100¢/ Mcf	125¢/ Mcf	150¢/ Mcf	200¢/ Mcf	Re-mainder	Total Basin Potential
Sverdrup—Onshore	31.0	52.0	68.5	78.5	85.5	91.0	95.5	104.0	107.5	113.0	118.5	0.3	118.8
Offshore	—	—	—	—	29.0	37.5	46.5	51.0	56.5	60.5	66.0	13.2	79.2
Arctic Fold Belt—Onshore	—	—	3.2	6.2	8.2	9.4	10.6	12.0	13.0	13.7	15.0	0.2	15.2
Offshore	—	—	—	—	—	—	—	—	1.7	2.6	4.0	2.8	6.8
Arctic Stable Platform—Onshore	—	—	—	—	—	—	—	—	—	0.3	0.6	0.0	0.6
Offshore	—	—	—	—	—	—	—	—	—	—	—	0.6	0.6
Arctic Coastal Plain—Offshore	—	—	—	—	—	5.8	8.0	11.0	13.6	14.9	17.0	3.8	20.8
Beaufort Mackenzie—Onshore	—	19.0	26.8	32.5	36.1	38.0	39.8	42.5	45.0	46.5	49.0	1.0	50.0
Offshore	—	—	—	—	—	14.0	17.5	24.0	28.5	32.0	35.5	8.0	43.5
N.W.T. Mainland	—	—	1.9	2.9	4.0	5.0	5.6	6.4	6.9	7.2	7.5	0.0	7.5
West Coast—Offshore	—	—	—	—	—	—	0.6	1.2	1.9	2.4	3.0	0.6	3.6
Scotian Basin—Shelf	—	—	—	—	8.8	12.5	13.8	21.2	25.0	27.0	28.0	0.0	28.0
Slope	—	—	—	—	—	—	—	—	—	—	6.7	35.4	42.1
Avalon Uplift—Shelf	—	—	—	—	0.2	0.3	0.5	0.7	1.0	1.2	1.4	0.5	1.9
Slope	—	—	—	—	—	—	—	—	—	—	2.5	10.4	12.9
East Newfoundland—Shelf	—	—	11.0	18.0	22.5	27.2	29.3	35.0	41.0	46.3	52.0	8.9	60.9
Slope	—	—	—	—	—	—	—	—	7.2	10.5	15.0	16.3	31.3
Labrador Shelf and Slope	—	—	—	—	5.8	9.3	10.4	16.0	19.3	22.0	26.0	12.7	38.7
Baffin Island Shelf and Slope and Atlantic Rise	—	—	—	22.5	30.0	36.0	40.5	48.5	56.0	62.0	69.4	21.9	91.3
Hudson Platform	—	—	—	—	—	—	—	—	—	0.8	1.8	5.5	7.3
St. Lawrence Platform and Maritime Basins	—	—	—	—	—	—	—	—	2.5	4.5	7.6	5.1	12.7
Total	31.0	71.0	111.4	160.6	230.1	286.0	318.6	373.5	426.6	467.4	527.5	147.2	673.7

TABLE 6

(Oil 1972)

CANADA FRONTIER AREAS—COMPOSITE OIL SUPPLY CURVE DELIVERED COST

(1972 Potential Estimates)

	Transport Tariff	Potential Oil Available at Delivery Price, Billions of Barrels										Total Basin
	$/Bbl	$2.00	$3.00	$4.00	$5.00	$6.00	$7.00	$8.00	$9.00	$10.00	$15.00	Potential
Northern Canada												
Mackenzie North	1.00	2.0	4.4	5.1	5.5	5.7	5.8	5.9	6.0	6.1	6.4	7.4
Mackenzie South	0.70	0.2	0.6	0.9	1.0	1.1	1.2	1.2	1.3	1.3	1.4	1.4
Beaufort Sea & Arctic Islands Offshore	1.25	-0-	-0-	13.3	17.6	20.4	22.5	24.3	25.8	27.1	31.0	43.8
Sverdrup Basin Onshore—(Tanker)	0.75	1.3	2.2	2.6	2.8	2.9	3.0	3.1	3.1	3.2	3.3	3.6
(Pipeline)	1.25	0	3.7	4.9	5.4	5.7	5.9	6.0	6.2	6.3	6.5	7.3
Arctic Islands Onshore Lowlands, Fold Belt, Platform	1.00	0	0.5	1.3	2.2	2.9	3.4	3.9	4.3	4.5	5.5	6.7
Eastern Canada												
Scotian Shelf, Sydney	-0-	-0-	0.8	1.4	2.0	2.5	2.9	3.3	3.6	3.8	4.6	5.8
Grand Banks	0.25	1.7	2.7	3.3	3.6	3.9	4.1	4.3	4.4	4.5	4.8	5.0
Labrador Shelf	0.50	-0-	0.3	0.7	1.0	1.2	1.3	1.5	1.6	1.7	2.0	3.1
Atlantic & Labrador Slopes & Baffin Basin	0.50	-0-	3.1	7.3	9.3	10.8	11.9	12.8	13.5	14.2	16.5	24.6
Hudson Bay, Foxe Basin	0.75	-0-	-0-	-0-	-0-	0.2	0.2	0.3	0.4	0.4	0.7	1.5
West Coast												
West Coast Offshore	-0-	-0-	0.2	0.3	0.4	0.5	0.6	0.7	0.7	0.8	0.9	1.2
Grand Total for Canada		5.2	18.5	41.1	50.8	57.8	62.8	67.3	70.9	73.9	83.6	111.4

TABLE 7

CANADA FRONTIER AREAS—COMPOSITE OIL SUPPLY CURVE DELIVERED COST

(1973 Potential Estimates)

	Potential Oil Available at Delivery Price, Billions of Barrels										Total Basin	Transport Tariff
	$2.00	$3.00	$4.00	$5.00	$6.00	$7.00	$8.00	$9.00	$10.00	$15.00	Potential	$/Bbl
Northern Canada												
Sverdrup Basin—Onshore (Tanker)	—	0.6	1.0	1.3	1.5	1.7	1.8	2.0	2.1	2.5	3.0	0.75
Onshore (Pipeline)	—	0.4	1.2	1.7	2.0	2.2	2.5	2.6	2.8	3.2	4.2	1.25
Offshore (Pipeline)					—	0.2	0.4	0.5	0.6	0.9	2.2	1.35
Offshore (Tanker)				—	0.1	0.3	0.5	0.6	0.7	1.0	2.5	0.85
Arctic Fold Belt—Onshore		0.5	1.1	1.5	1.7	1.9	2.0	2.1	2.2	2.4	2.6	0.75&1.25
Offshore									–0–	–0–	1.1	1.15
Arctic Stable Platform—Onshore				0.1	0.2	0.3	0.4	0.4	0.4	0.6	0.6	1.00
Offshore									–0–	–0–	0.6	1.10
Arctic Coastal Plain						0.4	0.6	0.8	1.0	1.5	3.5	1.35
Beaufort-Mackenzie—Onshore		0.7	1.2	1.5	1.7	1.9	2.1	2.2	2.3	2.7	3.5	1.00
Offshore					0.1	0.3	0.5	0.6	0.7	1.1	2.7	1.10
NWT Mainland		0.5	0.8	1.0	1.1	1.2	1.3	1.4	1.4	1.6	1.7	0.70
Eastern Canada												
Scotian Basin—Shelf	0.6	1.2	1.5	1.8	2.0	2.1	2.3	2.4	2.5	2.8	3.4	–0–
Slope				0.4	0.8	1.1	1.4	1.6	1.8	2.5	5.8	–0–
Avalon Uplift—Shelf		—	0.1	0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.4	0.25
Slope							—	0.1	0.2	0.4	7.2	0.25
East Newfoundland—Shelf	3.8	6.0	7.2	8.1	8.7	9.1	9.4	9.7	10.0	10.4	10.6	0.25
Slope				—	0.5	0.8	1.1	1.3	1.5	2.1	4.9	0.25
Labrador Shelf	—	0.3	1.1	1.6	1.9	2.2	2.5	2.7	2.8	3.5	5.5	0.50
Baffin Island, Atlantic Slope	—	2.4	4.4	5.6	6.6	7.2	7.9	8.3	8.8	10.2	14.7	0.75
St. Lawrence Platform		—	0.4	0.6	0.7	0.8	0.9	1.0	1.0	1.2	1.5	–0–
Hudson Platform					0.1	0.2	0.3	0.4	0.6	1.2	1.5	0.75
West Coast				0.1	0.2	0.2	0.3	0.3	0.3	0.4	0.6	–0–

TABLE 8

CANADA FRONTIER AREAS—COMPOSITE GAS SUPPLY CURVE DELIVERED COST

(1972 Potential Estimates)

	Transport Tariff ¢/Mcf	Potential Gas Available at Delivery Price, TCF									Total Basin Potential
		90¢/Mcf	100¢/Mcf	110¢/Mcf	120¢/Mcf	130¢/Mcf	140¢/Mcf	150¢/Mcf	160¢/Mcf	175¢/Mcf	
Northern Canada											
Mackenzie North	75	–0–	11	21	27	30	32	34	36	38	48
Mackenzie South	60	1	3	4	6	7	7	8	8	9	11
Beaufort Sea & Arctic Islands Offshore	90–105						0	28	90	114	319
Sverdrup Basin Onshore	95			0	18	30	39	44	48	53	65
Arctic Islands Onshore Lowlands, Fold Belt, Platform	100						3	5	8	13	40
Eastern Canada											
Scotian Shelf, Sydney	35	9	12	15	17	18	20	21	22	23	34
Grand Banks	60	7	12	15	17	19	20	21	22	23	30
Labrador Shelf	60				4	5	6	7	8	9	18
Atlantic & Labrador Slopes & Baffin Basin	70					41	55	64	70	88	147
Hudson Bay, Foxe Basin	35					1	1	2	2	2	9
West Coast											
West Coast Offshore	35	2	3	3	4	4	4	4	5	5	7
Grand Total for Canada		19	41	58	93	155	187	238	319	377	728

TABLE 9

(Gas 1973)

CANADA FRONTIER AREAS—COMPOSITE GAS SUPPLY CURVE DELIVERED COST

(1973 Potential Estimates)

	Transport Tariff ¢/Mcf	Potential Gas Available at Delivery Price, TCF 90¢/Mcf	100¢/Mcf	110¢/Mcf	120¢/Mcf	130¢/Mcf	140¢/Mcf	150¢/Mcf	160¢/Mcf	175¢/Mcf	Total Basin Potential
Northern Canada											
Sverdrup Basin—Onshore	95				36	62	74	83	89	96	120.0
Offshore	100							10	30	41	78.0
Arctic Fold Belt—Onshore	100					—	3	7	8	10	15.0
Offshore	105									0	7.0
Arctic Platform—Onshore	100									0	0.6
Offshore	105									0	0.6
Arctic Coastal Plain	105								—	5	20.8
Beaufort-Mackenzie—Onshore	75		12	25	30	34	37	39	41	43	50.0
Offshore	90							11	15	20	43.5
NWT Mainland	60		2	3	4	5	6	6	6	7	7.5
Eastern Canada											
Scotian Basin—Shelf	35	6	12	15	18	20	22	23	24	26	30.1
Slope	40									0	40.0
Avalon Uplift—Shelf	60									1	1.8
Slope	65									0	13.0
East Newfoundland—Shelf	60		11	18	23	26	30	32	35	38	58.6
Slope	65									5	33.6
Labrador Shelf & Slope	60				6	10	12	14	16	18	38.7
Baffin Island, Atlantic Rise	75			6	18	26	33	39	44	49	91.3
St. Lawrence & Maritime	15			1	1	2	3	3	4	5	12.7
Other Areas											
Hudson Platform	35									1	7.3

Chapter 4

THE PRIORITIES FOR FUTURE SCIENTIFIC ACTIVITIES

Introduction

There is a need for better knowledge of our energy resource base, and a need for scientific activities to ensure that adequate reserves are located and developed to meet our energy needs in a timely manner. There are a number of constraints which will require further scientific and technological investigations before parts of our resource base can be made available for potential use. The adequacy of existing levels of funding, and institutional structures, to meet these science challenges requires further definition and must be linked to our national science policies. These matters must be resolved on an urgent basis if Canadians are to be assured of a variety of energy sources at competitive prices.

Our supply and demand forecasts have shown that Canada has an adequate energy resource base for our domestic needs and will be in a position to be a net exporter of some energy forms for some time. In the very long term our exports will diminish unless major new resources are discovered. Even to meet our domestic needs, there will be changes from our present supply and demand pattern as energy prices increase, our readily accessible petroleum is consumed, and we proceed to develop more remote and costly sources of fossil or alternative fuels.

Not only will there be changes in our basic resource supply, but there will also be changes in our modes of recovery, transport, conversion and usage. Changes in our energy industries are also taking place as a direct result of the worldwide movement towards better protection of the natural environment. All these changes require new technology, and in some cases require substitution of traditional supplies with others that are more acceptable.

There is worldwide concern at the foreseeable increase in total energy consumption in the face of dwindling fossil fuel reserves. The solution to our future needs is seen to be the development of new energy sources, of which nuclear energy is of most immediate importance. In order to provide enough lead time for the orderly development of these new energy sources there is a need to introduce thoughtful conservation and to improve the efficiency of use of known fossil reserves thereby providing a breathing space in the race to the new technologies. To some extent conservation of energy may minimize the environmental impact of growing energy use, but the major improvement in environmental protection will be the consequence of new technology which, in the first instance at least, may reduce rather than improve efficiency of use, i.e. automotive emission control equipment.

Coincident with the rising cost of energy, particularly energy derived from petroleum products, research programs are being accelerated in many parts of the world to provide new technology. Some of this new work will be applicable to Canadian needs, but there are unique aspects of our energy situation that must be investigated in Canada for our specific requirements. In addition to new technology relating to extraction, production and use, the planning of our resource policies will require improvement in our knowledge of our energy resource base. Geological and geophysical surveys must be extended, particularly in those remote parts of Canada now identified as probable sources of hydrocarbons. The extent of known deposits of liquid, solid and gaseous fossil fuels must be more accurately determined. The quality of those less concentrated sources of energy such as the oil sands, the leaner uranium deposits, and some of our coals, should be fully evaluated in the light of our current recovery techniques and possible conversion processes. And finally, this information must be correlated and analysed to ensure that our development priorities are appropriate.

Research Priorities and the Time Scale of Development

Over the long term, it is obvious that Canadians must utilize higher cost fossil fuels and to a greater and greater extent these will be replaced by nuclear fuels and perhaps other energy sources which are now at a very elementary state of development. Since a workable technology for producing nuclear energy now exists, the requirements for this long-term transition will be related mainly to the problems of utilizing electricity for many services now performed by fossil fuels. A continuing level of research will also be required to ensure that our nuclear electrical generators are safe, non-polluting and as economically efficient as possible. Incentives to innovation in the greater and more efficient use of electricity can be expected to develop naturally as the price of fossil fuels and their derivatives increase. Research into techniques to conserve nuclear fuels should not be disregarded but are less important to Canada, in view of the abundance of our uranium deposits, the efficiency of the CANDU reactor and the limited effect of uranium costs on the end cost of energy.

In the shorter term high priority must be given to the scientific investigations required for the development of remote and less accessible oil and gas, oil sands, and coal. Of these three resources the oil sands now appear the most promising for our needs of liquid fuels over the next century and warrants the highest research and development priority. The rate of oil sand development will depend largely on our success in the discovery of conventional oil and gas deposits and the cost of developing those deposits.

There is an immediate need for R&D related to the exploration and production of Arctic and offshore petroleum, and in particular, investigations must be continued on the social and ecological questions being raised in connection with these developments.

The role of liquid fuels is destined to play a smaller part in our future economy, but there are two important uses for which liquids are particularly suited, i.e. personal transportation and aviation. Canada will still require an adequate supply of liquid fuels for these specific uses for many years into the future, and we

should strive to improve their efficiency of use for these purposes. As our conventional oil reserves become depleted the oil sands will become a major supplier of these liquids. However, as the richest and most accessible oil sand deposits are consumed, oil sand products will increase in cost. An alternative that may then become attractive would be the liquefaction of coal. Canada has substantial coal deposits that may be converted to liquids using presently available technology, and this might be done at a lower cost than extraction of some of the less productive oil sand areas. The processing steps required for coal liquefaction are technically similar to those used in the refining of oil sand bitumen, and the use of coal has one advantage over oil sands in that the carbon content of the coal deposit will be much greater than in oil sands. For this reason, research into coal liquefaction should proceed parallel with oil sand research, to ensure that we adopt the most economic of these two alternatives.

Natural gas has played a dominant role in the North American energy economy, primarily due to its low cost. It also has certain inherent advantages, including low cost transportability in pipelines, low generation of pollutants during combustion, and certain advantages in the combustion process such as ease of control and minimum combustion equipment. A major question arises as to whether the general use of gaseous fuel should continue when reserves of natural gas are depleted. A body of opinion is now developing that it should be replaced by hydrogen. Hydrogen has most of the advantages of natural gas and, in addition, may be generated by the processing of any fossil fuel or by the electrical decomposition of water. It may also be transported at much lower cost than electrical power. Hydrogen is presently too expensive to be used as a fuel, but it is now important in the liquefaction of coal. For all these reasons, hydrogen technology warrants research effort.

Summarizing the chronology of these forecasts, it can be expected that nuclear power generation will provide an increasing proportion of total energy needs over the next 30 years and beyond, and research in this area should be considered as a continuous development and improvement effort.

Research into various aspects of the development of the oil sands is identified as a top immediate priority. Present production of synthetic crude oil from the oil sands is about 40,000 barrels a day, compared to nearly two million of crude oil production. However, oil sands production is expected to provide as much as 300,000 to 500,000 barrels a day by 1980. There will be great difficulties in meeting those levels, not only for technical reasons, but also due to organizational difficulties and to competition for capital. Some of the specific research needs are discussed below. The need for in situ extraction of the deeper oil sand deposits will not likely be needed much before the end of the century, but research should nevertheless receive priority in view of the longer term potential, and also because in situ recovery methods may prove to be competitive with surface mining for the shorter term.

The use of coal is expected to grow, but the extent of its use is very much dependent on the degree of success in locating new reserves of oil and gas, and economical methods of oil sand recovery. Another consideration is the high level of coal research activity elsewhere in the world. For these reasons it has been assigned a lower priority than oil sands, petroleum and nuclear energy; but this may well be revised in the future and a continuing research effort is certainly justified.

Those energy sources and conversion processes at an early stage of development, such as geothermal, solar, wind, fuel cells, magnetohydrodynamics and thermionics are not presently expected to be important to Canada in this century. Having consideration to the size of our research capability, these sources do not warrant research support beyond the monitoring of activities in other countries and perhaps a more extensive inventory of geothermal "hot spots" in Canada. Any technical breakthroughs in these areas, however, may dictate a shift in priorities.

The above priority considerations refer to what is generally defined as research and development. A major priority outside the limits of this specific activity is the improvement of our basic knowledge of the extent, accessibility and quality of the resource base. If this basic information is inaccurate or incomplete, all of our planning and policy development is of dubious value.

Specific Fields of Energy Research

Consideration of individual research needs within the various energy sectors are discussed in more detail in the following sections:

Oil Sands

The Athabasca oil sands represent an enormous reserve of hydrocarbons, but it is one that is not technically easy to recover, and the major part of this reserve is uneconomic to recover at present oil price levels. Research work on the oil sands has been carried on for several decades, but it was 1968 before the first recovery plant went into operation. The oil sands now being recovered are the most attractive economically, being close to the surface and easily mined, and containing percentages of hydrocarbon in excess of 10%. As future requirements demand a more extensive exploitation of this resource, it will become necessary first to improve the economics of recovery from less concentrated sands, and second, to recover sands lying at considerable depths where surface mining is not feasible. Our research needs will, therefore, centre around the following subjects, with environmental considerations in each case:

Improvements to the techniques of mining, including transportation of the sand to the processing plant, and restoration of the mined areas.

Improvement to the oil recovery process, now commercially done by a hot water flotation method, and solution to the current acute problem of the disposal of water tailings containing a suspension of silt, that cannot be separated by gravity or an economical filtration system.

Improvements to the process for the upgrading of the oil to usable oil products. The presently operating plant thermally decomposes the oil to lighter liquid products and to a coke containing much of the sulphur content of the oil. The liquid products are further refined by hydrogenation and reblended to make a so-called synthetic crude oil. The coke has been burnt to generate steam for the extraction and refining processes, however, this gives rise to excessive sulphur dioxide pollution and has had to be curtailed

to meet Alberta's strict pollution controls. Future processing should avoid this problem, probably by the use of hydrocracking instead of coking. Various other processing sequences are feasible and research is needed to improve the economics of this step.

In the refining of the oil to make "synthetic crude", sulphur is removed by hydrogen treating and recovered as elemental sulphur. Disposal of this sulphur has become a problem due to a worldwide surplus of sulphur and a slump in prices. This problem also afflicts the natural gas and refining industries, and is discussed in a separate section below.

The recovery of the deposits at extreme depths will require the development of in situ recovery methods. A number of such methods have been considered, many of which have also been used or considered for the recovery of inaccessible deposits of petroleum or coal. In general these methods require the generation of heat within the deposit to cause it to flow, and the application of pressure to bring the fluidized material to the surface. The use of nuclear energy for this purpose has been considered in the past but discarded for technical and other reasons.

Conventional Oil and Gas

Although oil and gas have been recovered by drilling for over a century, and a tremendous expenditure has been made in research on the science of petroleum formation, there is still a basic lack of knowledge on this subject. It is still necessary to find oil or gas by trial and error methods and the number of dry exploratory wells far exceeds the number of producing wells. Whereas the extent of coal beds is relatively easy to assess, since coal lies in beds with lateral continuity, the location and extent of oil deposits has proved extremely difficult to predict. Knowledge is lacking both on the formation and migration of petroleum. Considering the extremely high cost of drilling in the areas now being explored, it follows that the return on investment in better geophysical and geochemical knowledge should be high. While the geoscientists play the major role in this research, statistical work is also of major importance in the correlation of data on known petroleum deposits.

Canadian oil and gas research needs are also modified by the problems of Arctic operation, and the particular concern for damage to the sensitive northern ecology. It is also necessary to do research into sociological factors related to the arrival of exploration work forces in an area previously inhabited mainly by native peoples. On the environmental side, there is need for research on the effect of pipelines, roads and other activities on permafrost and on the wildlife. The low temperatures experienced create specific problems with materials; many steels become brittle at such temperatures and engineering standards must be modified accordingly. Research is also needed into the problems of normal human existence in these areas including the logistics of supply and transportation, and the type of community most suited to the area. Waste disposal is a particularly important problem in view of the low rate of decomposition of organic matter.

The continental shelves of the world have been shown to be one of the most important areas for future petroleum production and generally have produced

higher yields per acre than onshore. Although the basic principles of drilling and production are the same offshore as onshore, and active developments are underway in the improvement of offshore drilling structures, drilling ships and underwater completion systems, we need more research into the specific problems posed by the ice infested waters of the Arctic offshore.

In order to extend the life of our petroleum reserves, further research into secondary and tertiary recovery techniques is also warranted.

Refining technology is mature, and research needs are generally limited to reducing air and water pollution, as well as reducing the noise and improving the general acceptance of refineries by residential communities. Waste disposal is becoming a continuously increasing cost factor to the refiner, and there is economic justification for the further development of waste disposal facilities capable of handling the ever increasing volume and variety of industrial and chemical wastes.

Refining technology is available for the manufacture of new fuel products to meet current environmental standards, e.g., the reduction of lead in gasoline. However, this can only be done at a price. To produce a no or low-lead gasoline with satisfactory operating characteristics effectively wastes about 10% of liquid fuel resources. This is a considerable sacrifice to meet problems that have other solutions, i.e. more efficient non-polluting engines. Similarly high sulphur residual fuels can be desulphurized by hydrogenation, but the economics are not attractive.

The most important research need related to the use of petroleum, is the development of fuels and engines conducive to the reduction of automobile emissions. No proven technology has yet been developed to meet U.S. 1976 environmental standards, in spite of extremely large research expenditures. A major research effort towards lower polluting engines is outside Canada's present capability, but there is a requirement for accurate information on the extent of the pollution hazards from automobile exhausts under Canadian conditions.

Electricity

The prospect is for a sixfold growth in the demand for electricity in the next 30 years. By the year 2000, about 50% of the nation's increasing energy consumption will be in the form of electricity. Thus, a major research thrust should be directed to the generation, transmission and consumption of electricity. For example, given that with the exception of hydro power the resources consumed in the generation of electricity are non-renewable and limited in various degrees, and that the cost of these resources, particularly coal and petroleum, will increase progressively and significantly, special effort should be focused on improving the efficiency with which the potential energy in the fuels consumed is transformed into electrical energy. The overall efficiency of thermal plants burning fossil fuels is less than 40% at best and is nearer 30% for power generation by current types of fission reactors. Further gains in efficiency will require considerable research effort.

In the field of hydroelectric generation, although most of the favourable sites have already been exploited, further progress can be made through development of low head plants. Similar plants would be suitable for harnessing tidal power. The further development of pumped storage systems may also be warranted

to permit the large nuclear generating stations of the future to run at steady loads, thereby minimizing the average cost of energy from the capital intensive nuclear plants. In addition, much more environment research is required to improve our understanding of the impact of hydroelectric projects in specific geographic areas.

The size of Canada being what it is, the efficiency of power transmission is important. Much has been accomplished to reduce capital costs, and also transmission losses, by using high voltage alternating current. Voltages are expected to continue to grow to the 1,000 to 1,500 kilovolt range in future. The increasing use of direct current transmission is also a distinct possibility. If significant improvements can be achieved in long distance transmission, it may become economic to locate fossil fueled thermal generating stations close to the mine site —particularly of low grade coals where the transportation costs per Btu might otherwise be high. Transmission studies should also be considered in relation to alternative methods of energy transportation such as pipelines.

Much future transmission research will be related to environmental concerns; for example, the optimum routing of transmission corridors, and the use of underground transmission. Research is underway elsewhere to develop new alloys capable of superconductivity at higher temperatures than existing superconductors, but the work does not warrant a high priority in Canada.

In the area of power consumption there are significant opportunities to improve the efficiency of industrial processes, industrial machinery and domestic appliances, and in indoor climate control.

Uranium and Nuclear Energy

Nuclear power is expected to provide half of the new electrical capacity between now and the year 2000 or about 100,000 MW compared to the 6,000 in operation or under construction today. Hence, in the context of the nation's energy needs, and the relative immaturity of the technology, R&D on nuclear energy should continue to command a high priority.

Although the demand for uranium is not very active at the moment, it is growing rapidly. Canada's present share of world markets is about 20%. A similar percentage of the estimated 1980 world market would be 14,000 tons U_3O_8/year, which may be compared to an estimated Canadian capacity of about 13,000 tons based upon deposits which are now being mined or developed. Because the interval between initial geological exploration and a producing mine is eight to ten years, work should be stepped up immediately on gathering the basic scientific data to indicate the more favourable regions of uraniferous potential.

There is a need for continuing research on a variety of ore processing problems. Canadian ores tend to be lean in uranium, yet they contain other valuable elements, such as thorium and the rare earths which are recoverable. Further work is necessary on bacterial leaching and other recovery processes to improve the competitiveness of uranium production, especially in view of the environmental quality standards which the industry will be expected to meet. In the field of chemical processing, work to develop lower cost procedures for recovering plutonium from spent fuel is very desirable. With current methods, it will be

more than a decade before a plutonium extraction plant will be economically viable. Reduced plutonium recovery costs hasten the day when smaller reactors burning slightly enriched fuel offer sufficient economic incentive to warrant development of a supplement to the natural uranium reactor.

From an environmental viewpoint, a significant problem is the safe transportation, storage and disposal of radioactive materials. The spent fuel, after it is discharged from the reactor contains a spectrum of radioactive isotopes, some of which have half-lives measured in thousands of years and thus will remain a hazard for generations to come. Thus, as nuclear reactors come on stream, they will generate radioactive wastes which will dictate the evolution of safe management and disposal systems. Spent fuel from reactors at Bruce and Pickering is stored, safely enough for the time being, in on-site "swimming pools". Above ground concrete structures are being proposed for long-term storage but further work is necessary to determine if a permanent safe disposal method can be achieved, such as placement in salt domes or caverns in geologically stable regions. Methods have been technically demonstrated for converting the wastes into a stable glass. Further studies are required to develop lower cost stable forms, identify stable geological structures, and to explore other means of safely and permanently disposing of radioactive waste.

The safety of nuclear power plants and other facilities used for handling and processing radioactive substances warrants continuing attention. Since the risk of human exposure to, and environmental contamination by, radioactive materials must be reduced to very low limits, there is an ever present need for greater reliability in safety systems. Although present plants are considered safe, the greatly increased number of nuclear power plants demands that the already stringent safety standards be increased even further. As the fundamental assurance of safety is the integrity of the plant itself, better methods and techniques of in-service monitoring and non-destructive testing are required. Continued study is necessary to understand in further detail all the complex nuclear and other reactions which have a bearing on the integrity and safe operation of nuclear power plants.

Per unit of electricity generated, the low-temperature heat discharged in the cooling water from a thermal nuclear power station approaches 50% more than that discharged from a fossil fuel burning plant. With the proliferation of nuclear power stations in the future, the problem of thermal discharges to the environment will become even more important. Current studies indicate that heat rejected from generating stations in Canada will increase from about 3×10^{10} Btu/hr in 1970 to 100×10^{10} Btu/hr in 2000. This indicates a 33-fold increase in heat rejection rate during a 30-year period and, of course, a substantial increase in cooling water requirements.

Further research is necessary to reduce the magnitude of thermal loss, but more important, Canada's climate may provide opportunities for researchers to develop beneficial uses of low-grade waste heat.

In view of the crucial importance of heavy water to the viability of the CANDU reactor program and the present serious shortage, further development work on the process presently used in Canada—the so-called GS process—as well as studies of alternative processes are justified.

Coal

Canada's coal reserves are estimated to be a major source of fossil energy, second only to the oil sands. Ninety-five per cent of these reserves are in Western Canada, and are characterized by a low sulphur content—averaging 0.6% compared with 5% for Athabasca bitumen—and thus have a significant advantage in this respect.

As past demand for coal has yielded continuously to the convenience and cleanliness of oil and gas, the coal industry in Canada, as elsewhere, has been in decline. However, recent long-term contracts with Japan for the supply of metallurgical coal have brought an upturn in mining activity in Alberta and British Columbia and with the increasing costs of Albertan oil and gas, the outlook now in the Prairie Provinces for coal for electricity generation is brighter. However, while a long-term supply is assured, demand must be satisfied in ways that are acceptable, especially from an environmental point of view. Because of the role of increasing importance that coal will play in meeting Canada's energy needs, research and development directed towards solving problems associated with the evaluation, mining, distribution and consumption of coal warrants continued and expanded attention.

While future supplies of coal appear abundant, much of it occurs in areas where past earth movements have distorted the seams to a point where mining is difficult and costly and the quality of the coal is uneven. In these highly distorted formations, there is need for detailed geological analysis both to determine the amount of coal present and to locate and characterize the deposits.

In addition to the need to improve the evaluation of our coal resources, we need research into a number of technical problems including the following:

More economical extraction methods, suitable for the specific mining conditions existing in Canadian coal fields.

More efficient beneficiation to meet market specifications.

More efficient transportation, particularly to deliver western coals to eastern markets. Coal pipelining has been under study and further work is justified. Coal/oil slurries are promising, and these slurries may be used directly as fuel, or conceivably as feedstock for further processing steps to refined products.

The development of more efficient heat recovery in thermal generating plants. Improvements may be made by the use of "combined cycle" systems, such as the use of a gas turbine powered by gasified coal followed by a steam turbine.

Gasification of coal, using several established techniques, has been used for many years, but generally has been displaced by the increasing availability of natural gas. As natural gas prices increase in the future, coal gasification may stage a come-back. Future plants, however, are likely to use more sophisticated technology, and if research can reduce costs, this gas may provide strong competition for natural gas, and place a ceiling on natural gas prices.

Liquefaction of coal may take on a specific importance in the future in view of the advantages of a liquid fuel for personal transportation and aviation. There are several established techniques available, originating in German work during the second world war. A government-owned plant has also been in commercial operation in South Africa since 1955, justified by security of supply rather than economics. Costs of these liquid fuels are currently claimed to be in the $4 to $6 per barrel range, and may well be economic in Canada before the end of this century. We should certainly monitor current research in this field, now actively pursued in the U.S., in relation to our competing tar-sand recovery processes.

There are certain safety aspects of coal mining that warrant further research. Devices should be developed to automatically detect the presence of spontaneous combustion and monitor the analyzed results. Continuous monitoring of mine air, to detect toxic gases and ensure adequate oxygen, is also needed. Further research into rock mechanics, is required for the control of sedimentary strata overlying coal seams.

Environmental protection research is needed, related to the control of acid mine waters, the suppression of coal dust, and reduction of pollutants emitted during coal combustion.

The carbonization of metallurgical coking coals is related to their use as fuel, and further research is proposed in this area.

Sulphur Removal and Utilization

A mounting problem to the energy industry is the growing stockpile of sulphur. The principal source of this is the hydrogen sulphide extracted from natural gas. Desulphurization during the distillation of fuel products and sulphur recovered from ores contribute smaller quantities. Production increased from 0.25 million tons in 1959 to 6.6 million tons in 1972. During this period Canada changed from being a net importer of sulphur to becoming the world's largest exporter, providing 35% of the international trade in this commodity. In the last six years the surplus has grown to its current level of more than 8.6 million tons and the price has fallen from $35 to $6 per ton. This trend has greatly increased the cost to the petroleum industry of providing clean fuel.

In this situation, progress has been made towards establishing an institute to conduct research into finding new uses for sulphur. Suggestions based on previous work include its use as a material in road paving asphalt, use as a component in an aggregate mix to be known as sulphacrete, and application in the form of a foam in insulating materials. This work is important. As advancing numbers of fuel burning installations comply with environmental standards, as the consumption of fossil fuels grows and as fuels tend to become more "dirty", there will likely be ever increasing stockpiles of sulphur unless new uses for it are developed.

Tidal Power

The prospect of generating power by harnessing the tides has proved irresistible to some, and as the site of greatest potential, attention has focused on the Bay

of Fundy. The cyclic nature of the power generated poses very considerable engineering and power system problems, and the cost of tidal power is at present higher than that from thermal plants. Tidal power, however, has the advantages of being a non-depleting power source as well as being non-polluting. A federal-provincial group is at present reassessing the competitive position of Bay of Fundy power.

Other Sources

While the recommended outlines for Canada's main energy R&D effort have already been delineated, there are many other proposals for generating or converting energy which need further research. Although these are not considered as having a high priority in Canada at this time it is necessary to keep in touch with progress in these areas and where desirable, establish or maintain nuclei of expertise through judicious support. Specific proposals for funding, therefore, should be assessed on their own merits.

In the context of Canadian conditions the present status is as follows:

Wind Power. Originally conceived with the needs of underdeveloped countries in mind, a two- or three-blade, high-speed, vertical-shaft, rotor windmill has been developed that may have applications to specific Canadian situations particularly in the north. If the windmill is to have general application say, as a power source for isolated stations, a satisfactory power storage system must be developed. Power storage development is also needed for electric automobiles. As a means of generating small quantities of clean power, the work now being carried out on windmills appears promising and should be continued.

Solar Energy. Solar radiation is potentially the most abundant form of energy available to man and it seems probable that practical schemes will eventually be devised to harness it in useful quantities in regions with sustained sunshine. However, given the hours of sunshine above the 49th parallel during the months of greatest need, the possibility that it will make a significant contribution to Canada's energy needs, at least with the next two or three generations, seems remote in the extreme.

Geothermal Energy. The processes of geothermal power development can be divided into three basic "phases", as follows.

Phase 1: The exploitation of reservoirs of hot water that are clearly revealed by surface phenomena. Examples include all the currently producing sites in New Zealand, Iceland, Italy, etc. Many others are in the development stage now, for example Chile, Turkey.

Phase 2: The exploration for and development of energy reservoirs that are not clearly apparent. This activity is now in its infancy, but is encouraged by new facilities of satellite and airborne sensing.

Phase 3: The exploitation by means of some human assistance to the natural potential. This assistance may take the form of simple water circulation or may go the extent of nuclear explosions to induce fracturing and heat release at great depth in zones that are already hot. This phase is still in the conjecture stage.

In Canada Phase 1 does not apply; there are no obvious surface indications of hot water reservoirs. There are a few warm springs, with temperatures as high as 85°C at Lakelse, near Terrace, B.C., but there is no reason to believe that these springs could produce heat in large quantities.

Any geothermal power development in Canada must start at Phase 2. The potential does not appear to be large and it is probable, therefore, that any power generated by this means will not have much more than local significance. Nevertheless, proposals for support should be assessed on their merits.

Fast Breeder Reactors (*in relation to CANDU*). Several countries have an active program of research and development on breeder reactors. The impetus for these programs comes from the desire to use energy resources more extensively in the long term and, to a considerable degree, the desire to maintain nuclear energy research and development programs. Canada has not entered this field for three reasons: (1) the heavy-water-moderated natural uranium CANDU reactors have a low fuel cost which is particularly insensitive to rising uranium price; (2) Canada has large resources of uranium, and (3) the large expenditures necessary to develop breeder reactors are beyond the current scope of the Canadian research and development expenditures.

The essence of a breeder reactor is that it will produce more fissile material than it consumes; typically by converting the non-fissile uranium-238 (which constitutes 99.3% of natural uranium) to fissile plutonium-239. After allowing for inevitable processing losses this means that about 70% of the uranium resources can be used for energy production rather than the approximately 2% possible in most current reactor designs. The problem foreseen for breeder reactors, however, is a capital cost so high as to render them non-competitive against thermal reactors for many decades to come.

CANDU reactors are considered advanced converters; that is, they produce about 0.8 atoms of fissile material (uranium-239 or thorium) for every atom of fissile material consumed. By recycling the plutonium which is produced, the consumption of uranium can be reduced appreciably; for example by one recycle, the feed requirements are reduced by about 25%. Even with a once through system the fueling cost of CANDU reactors is less than 1 mill/kWh (electric). The efficiency of the CANDU system and potential variations is such that it is likely it can remain as an economic source of nuclear energy into the 21st century, when controlled fusion may be achieved.

Estimated resources of low cost ($15/lb.) uranium in Canada are about 900,000 tons U_3O_8 while the estimated cumulative demand for uranium for nuclear power in Canada (using the CANDU system) is about 100,000 tons to the year 2000. It is, therefore, the economics of the fuel cycle which determines when reprocessing and recycling of the plutonium should occur. Furthermore, the low fuel cost of the natural uranium cycle of CANDU reactors predicates against a fast breeder program. There is still some question whether or not the fueling cost of fast reactors will be as low as that currently available in the CANDU reactors. In addition the prototype fast reactors in the U.S., U.K. and elsewhere have a very high capital cost because of the technical complexities of such plants.

In the face of the favourable economics of the CANDU system, our large uranium resources, and our limited research and development funds, it is considered

unnecessary to enter into a program for breeder reactors for at least the next two decades, if ever. During that time, emphasis can be placed on the economics and technology of recycling plutonium and thorium in CANDU reactors. It would be prudent of course to keep a close technical watching brief on the fast breeder reactor programs in other countries.

Nuclear Fusion. Although controlled nuclear fusion offers the promise of almost unlimited energy, it has not yet been demonstrated as a laboratory reality. Estimates of the time when this will be demonstrated vary between 1980 and 2000. Judging from the development of the fission reactor it would likely take several decades after that to translate a laboratory device into a commercial energy source. As a result, even enthusiasts do not predict that a commercial controlled fusion energy source would be available before the year 2010. Nevertheless, for the very long term, fusion has the greatest potential of supplying our future energy needs.

Most of the current fusion research involves extremely expensive plasma equipment although there is a growing interest in laser triggered reactions. In the face of Canada's limited research funds and in the context of our extensive energy resources it appears that it would be adequate for the next decade or two for Canada to keep a good technical watching brief of developments elsewhere. Within this restriction it might be worthwhile to consider funding of model programs in associated or ancillary areas of research and development which would maintain a core of technically competent people and provide easier entry into the research in other countries.

Fuel Cells. The potential energy conversion efficiency of the fuel cell is an attractive research goal, but acute catalyst poisoning problems have prevented the development of devices which will operate satisfactorily with fuels of commercial quality. Current R&D effort in this field should be limited to monitoring the literature and selectively supporting applications for funding from universities and research centres as they occur.

Magnetohydrodynamics. Principally because of the operating temperatures required, the high theoretical power conversion efficiencies available with magnetohydrodynamic equipment have remained elusive. Typically, the operating lives of present M.H.D. devices are counted in tens of hours and it is for this reason that their use has been advocated for "topping" duties only—that is for operation at peak loads. Large-scale development in the U.K. and U.S. has been dropped and any proposals for future support in Canada should be scrutinized critically.

Thermo-Electric and Thermionic Devices. Here too are tales of early hopes dashed by practical difficulties. Considerable effort in the U.K. and U.S. has achieved no more than small, special purpose units of low efficiency. Unless future proposals are invested with new ideas, further development of these devices is a matter of low priority.

Hydrogen. Hydrogen has become increasingly important in the refining of petroleum, and large volumes are now also required for oil sand processing. It plays a key role in the desulphurization processes, important in the reduction of air

pollution. It has recently been suggested that it may play a far greater role in the future, when it might be used directly as a fuel.

Hydrogen would have some specific advantages as a fuel. It would be as easy to transport and to use as natural gas; be completely non-polluting; could be produced either from oil, gas, coal or electricity, and thus from nuclear or hydro power; and efficiently used in fuel cells. On the other hand, it is less suitable for use in transportation, and presently is far too costly to produce.

For the above reasons, research is now active in the technology of hydrogen production, and we should consider whether this might be related to the tar sands requirements, since hydrogen represents a significant element of cost in oil sand processing. Furthermore, it would be important in the economics of coal liquefaction.

CONCLUSIONS

Research and development efforts related to energy must be increased, to provide new technology for the rapidly developing changes in energy supply and use. Our present high level of effort in the nuclear field must continue, but a major change in direction is required towards a greater emphasis on the oil sands, northern resources, and towards the environmental aspects of all forms of energy. The extent of the change suggested becomes apparent from the following table, which reflects the findings of a 1971 study:

Item	Estimated Per cent of Federal Research Expenditures in 1972-73*
Nuclear energy	70.6
Coal	13.4
Oil and gas	10.6
Electrical energy	4.2
Tar sands	0.1
Other	1.1

*Excludes AECB grants. Total expenditure, approximately $96 million.

In order to ascertain what federal action is appropriate to execute new priorities, an inventory of present research work in this field is required, whether that work is done by governments, universities, industry, or elsewhere. Foreign work in all relevant areas must be examined. A study now being made by the Science Council will provide much of the required information. The measures that should be taken should be linked to our industrial development strategy, to ensure that Canadian industry plays a prominent role in the development and exploitation of new techniques.

A major task lies ahead in the analysis of this data on current R&D and in the development of specific recommendations for federal action. The Science Council Energy report, to be submitted during the second half of 1973, should provide the groundwork for these recommendations.

The financing of energy-related research would most logically be derived from revenue generated by the existing energy industries. It has been argued that some of the revenues derived from the sale of non-renewable resources, should be spent on research into new resource fields and that pricing should be adjusted accordingly.

In considering the energy policy requirements for R&D it would seem particularly appropriate that centres of excellence should be developed in areas of technology that are directly related to unique aspects of Canadian energy resources. Some of these unique areas include the oil sands; the development of energy resources under northern conditions of climate, geography and ecology; and the techniques to transmit energy efficiently over exceptionally long distances.

It is vitally necessary to press forward with global research on the environmental effects of discharges and emissions from different forms of energy development. Little is known about the long-term effects of sustained emissions to the atmosphere; of thermal discharges to the water; and of nuclear wastes to the entire environment.

APPENDIX A

PART 2. ENERGY AND THE NATURAL ENVIRONMENT

Chapter 1

THE RELATIONSHIP BETWEEN THE NATURAL ENVIRONMENT AND ENERGY POLICY

The evidence presented in Section II (Volume I) indicates that Canada has sufficient known total resources, exploitable with present technology, of uranium, tar sands and both metallurgical and thermal grade coal to satisfy for at least a century a domestic demand for basic energy that quadruples every thirty years. Regardless of whether such an exponentially growing demand will materialize, or whether it is in the national interest to attempt to meet it, it is clear that restrictions on overall use of energy in Canada and on development of Canadian energy resources are not likely to come from anticipated shortages of total energy supplies for national use. If such restrictions are applied, they are likely to be the result of concentrated selected demands on certain types of energy sources, arising from (i) external market pressures, (ii) the attractiveness of certain fuels under available or foreseeable technology, and (iii) environmental considerations.

Both the foreign market for Canadian energy supplies and the technical feasibility and social acceptability (and hence the price) of providing energy for selected uses, as for example in transportation, will be to a very large degree influenced by the effect on the environment of such energy production and use. Thus, environmental considerations will play a large and increasing part in shaping the demand on Canada's energy resources, and in the effectiveness and economy with which the demands are met and the resources managed. An integral part of the national energy policy must be concerned with the relationship between the production and use of energy and the natural and urban environment of Canada.

On a national scale, the use of energy in Canada has had little effect to date on the natural environment. Canadians are fortunate in that most, even those dwelling in the largest cities, have normally the opportunity to observe or enjoy, personally, the clean air, relatively pure water, and semi-natural forest, seacoast or prairie that is for the inhabitants of many other nations only a memory or a goal to be re-won after much effort and expense. But this very ambience of a clean and natural environment increases the contrast with an uncontrolled artificial one, and serves to alert Canadians to the dangers of some of our present practices. Canadians are very heavy per capita users of energy and material goods, and will continue to be so if we expect to maintain a comfortable urban life style under

the conditions of Canada's climate and geography. In the achieving of this life style we have already degraded the natural environment in local areas in a manner that is most remarkable for such a small population in such a large land.

In many cases it is the parts of Canada that are most productive and suitable for human activities, and hence most populous, that have been affected most; and we have the paradox that while most of Canada is a clean wild land, most Canadians live in a local environment whose quality is deteriorating. Such degradation of the environment is beginning to affect our current economy and social attitudes, and if unchecked it will decrease and in some cases destroy the value and usefulness of the land we pass on to future generations. An important objective of the national energy policy must therefore be to provide adequate energy for the country's needs, now and in the future, in the most efficient and economical manner while at the same time ensuring that on both a local and regional basis the long-term quality of the environment, in both tangible and intangible terms, is maintained at an acceptable level.

Although the effects on the environment of the production and use of energy are mostly local or regional, and, given time, neutralized by natural processes, certain impacts are global and cumulative. The continuing discharge of waste heat, of carbon dioxide, of some types of particulate matter that remain as suspended nuclei in the atmosphere, of persistent organic compounds in combustion products or of radioactive materials could conceivably ultimately cause an undesired and possibly irreversible change in the world environment. Canada's contribution to potential world environmental disturbance of this kind is small, but by no means negligible, and is large on a per capita basis. Thus, although the size of our energy resource base itself does not appear to indicate a need for restriction of energy use by Canadians, it is conceivable that quite aside from economic considerations, impending or potential global environmental changes could at some time make it imperative to decrease world energy use. Whether the need will be perceived in time, and whether a majority of nations will be willing and capable of changing their behaviour accordingly, is of course a concern for the future. As a heavy user of energy and one with a number of energy alternatives and an advanced energy technology, Canada has an obligation as a member of the world community of nations to take a leading part in the solution of global environmental problems arising from the use of energy, and in demonstrating how national needs for energy can be met without adding to the environmental problems of other nations or future generations. At the United Nations Conference on the Human Environment in June, 1972, Canada committed herself to work toward this end. Our national energy policy must enable Canada to meet this obligation.

There are several ways in which it might be possible to lessen the impact on the environment of the production and use of energy. One is simply to use less energy. As shown in Section II (Volume I), the use of energy in Canada is presently increasing at an accelerating rate which, if continued, will by the year 2000 be four times what it is today. It is not realistic, and may not be economically or socially desirable to reduce or reverse this trend suddenly, but, other things being

equal, if less energy is used, there will be less direct and cumulative effect by energy activities on the environment. The studies leading to the forecast of energy requirements summarized in Appendix A, Part 1, have shown that, if it is assumed that Canada will achieve the levels of population and economic activity presently anticipated, it might be possible through strict application of all feasible means of reducing energy use (better insulation, smaller cars, reduction of increased lighting, etc.), to decrease the projected level of energy consumption by about 20%. If such a policy of conservation of energy use while maintaining gross national product levels were applied, the use of energy in Canada in the year 2000 might be estimated to be three times what it is today (in contrast to nearly four times if present trends are unchecked); and thus if our energy practices and techniques continued to be similar to those of today the stress on the environment might correspondingly be estimated to be three times that of today. (It should be remembered that the effects on the environment are rarely directly proportional to the stress, but vary widely and sometimes drastically as tolerance and threshold levels are exceeded.) Any further reduction of energy use as a means of lessening environmental impact would appear to require a reduction either in projected population or economic activity.

Another way of lessening the undesired effects on the environment from energy production is to reduce, directly, the pollution, disturbance, or damage to the environment from the use of energy, regardless of the amount of energy used. If Canadians wished to have sufficient developed energy to meet their expected demands by the year 2000 and at the same time maintain or where desired reduce the present level of impact on the environment, the unwanted environmental effect per unit of energy used in Canada would by that time have to be reduced on the average to less than one quarter of what it is today. Information presently available gives grounds for concluding that, given the range of energy source materials available in Canada and the technology presently available or reasonably foreseeable in the near future, such a reduction in undesired environmental impact is feasible and that it can be achieved without disruption of the economy.

There is little firm evidence to support the suggestion that it will be necessary to curtail or restrict the total use of energy in Canada in order to protect the environment. Good management will demand that waste and inefficiency be minimized, in energy use as in other activities; but it is clear that the manner in which energy is used and its waste products disposed is much more important, in environmental terms, than how much energy is used. In some instances operations carried out using good environmental practices will use more energy than equivalent operations resulting in undesired environmental consequences. A proportion of the cost of environmental protection and enhancement is the cost of the extra energy used in design or operations to overcome the undesired effects of energy use.

It is considered unlikely that Canadians will follow a life style that will continue to result in a doubling of energy use every decade. Changes in population trends, considerations of the "quality of life", changed social goals and environmental consciousness, the simple filling up of habitable but presently uninhabited

space, and the maturing of the economy are all likely to reduce the continued acceleration of per capita energy use. Regardless of future trends, however, present information indicates that environmental control of energy production and use is much more effective in maintaining an acceptable present and future environment for Canada than restriction of energy use per se without prime attention to its environmental effects. The national energy policy, therefore, while discouraging wasteful and inefficient use of energy on mainly economic, social and resource management grounds, must contribute to maintenance and enhancement of the environment of Canada primarily by ensuring that energy is produced and used in an environmentally acceptable manner.

Chapter 2

THE DISTINCTIVE CANADIAN SITUATION

The energy, environmental, and conservation problems of each country are unique. Canada's national energy policy must be framed and applied in recognition of several factors that individually or together differ from those of other industrialized nations. Among many such factors which relate to environmental matters are the following:

Size and Composition of the Energy Resource Base

In comparison with its present and likely future domestic demand, Canada has a very large energy resource base. This includes a large proportion of uranium and natural gas, that have the highest potential for providing economical energy during the next several decades with comparatively fewer adverse effects on the environment than other fuels. With proper planning and control, Canada can use these resources to provide itself with ample supplies of a "cleaner" mixture of types of energy, based entirely upon domestic sources, than most other industrialized areas of the world.

This favoured situation has important environmental implications. Because decisions on whether to use foreign energy supplies (e.g. Venezuelan oil) can be based mainly on economic grounds rather than physical necessity, Canada can apply and evaluate environmental policies with regard to the use of energy with a minimum of constraints from trade policies or the physical availability of supplies. On the other hand, the large Canadian energy resources—particularly those that are environmentally "clean", are attractive in foreign markets, and conservation or environmental policies in other countries can have an important influence on the price and demand for Canadian energy materials. Canadians also must consider carefully the long-term effects on their own future "environmental options", of the export of "clean" fuels or energy.

At present, for example, we export "clean" gas so that Americans can generate power in accordance with their environmental regulations, and import "dirty" coal to generate power in Canada, with consequent environmental problems, then export some of the electricity so generated. This is practical economics today; is it practical environmentalism, and what of the future?

The Spatial Distribution of Energy-Environmental Impacts in Canada

The areas of most serious potential environmental damage from energy materials in Canada are in regional terms relatively small, scattered, and separated by areas where the disturbance is less. Even in our most heavily affected area, the Windsor-Quebec City belt, there is a high proportion of forest, farm land, and moving water, and a drainage system that originates in sparsely-inhabited non-industrialized zones. Although there are local areas that are highly polluted and considerably damaged, in the vicinity of nearly all of these areas there are, only a few miles away, extensive tracts of healthy vegetation where biological processes operate in reasonably balanced and near-natural manner. Provided that pollution concentrations and terrain disturbance are kept sufficiently small that no further damage takes place, and the present biota are left reasonably undisturbed, natural scavenging and neutralization processes can proceed. Canadians still have a good opportunity for maintaining a reservoir of healthy natural recovery capacity near most sources of environmental disturbance due to energy activities. In most other industrialized nations the areas of concentrated industrialization are more continuous and are less relieved by tracts of agricultural or forest land. Our energy policy must preserve and enhance this environmental advantage.

The Opportunity to Preserve "Natural" Land

Canada still has a large territory, encompassing a wide range of geographic zones, landscapes, and habitats, where the environmental disturbance due to human activities has been slight or negligible. Even with maximum development of our resources, only a small part of the presently undeveloped land need be directly involved in the production, transportation, or conversion of energy. It is still possible, in Canada, to plan for optimal use of natural land, and to apply land management policies so that land can be kept essentially undisturbed without handicapping the development of energy supplies. It is important that the energy policy ensures that steps are taken before development to prevent environmental damage, thus avoiding the need for rehabilitation.

The Relative Importance of Energy to Canadians

Many factors of the geography and demography of Canada tend to make the relationship between energy and the environment of particular importance to Canadians. The large physical size of Canada in relation to its population, and the strong concentration of population in a belt along the southern border, give us a distinctive pattern of energy use and a distinctive style of dependence on energy. Even within the continuously inhabited parts of Canada, Canadians are dispersed more widely than in most other countries, and our main settlements are separated by considerable distances. Canada's climate is marked by strong seasonal fluctuations with, in most parts of the country, a long period of biological dormancy, distinct but irregular times of cold, and in nearly all parts of the country, intervals

when due to snowfall, thaw, etc., movement of persons or goods becomes complicated. As a result of these circumstances Canadians use more energy per capita for basic transport, heating of houses and work areas, storage and distribution of food, etc. than the residents of any other industrialized nation except the U.S.S.R. to achieve the same degree of social communication, distribution of goods, and material standard of living. There is a basic level of individual and community energy use that is essential to survival of life in Canada; without it we would literally freeze and starve.

Canadians generally have subscribed to a life style developed in warmer and more densely populated parts of the world, and have used energy liberally to adapt this style to Canadian conditions. If they wished, Canadians could adopt a manner of living—multiple dwellings, mass transport, community heating, etc.—that might use less energy per capita; but we have not chosen to do so. As a society, we have preferred not to be frugal in our use of energy, but to consider that the advantages of a high-energy-consumption life style are well worth the cost of the energy. As a result, ample energy is personally important to the average Canadian, and he spends roughly as much of his income directly on energy—heat, light and personal transportation—as he does on food.

The individual Canadian is forcibly aware of the close relationship between the Canadian natural environment and energy costs; he sees manifestations of it ranging from the need for storm windows to the taxes for snow removal. An increasingly important component of the net energy cost is related to the undesired environmental impact of energy use and the price that must be paid, in dollars or changed behaviour or special equipment, to mitigate it. Energy thus plays a role in the life of Canada that may be relatively larger than in many other countries, and Canadians individually are for the most part well aware of its importance in making their environment liveable and of its potential for degrading environmental quality.

The Effect of the Canadian Climate and Geological History on the Behaviour of Pollutants

The climate, the physical geography and the geological history result in aspects of our physical and biological environment that are affected in a distinctive way by our use of energy. For several months of the year, essentially all of Canada's land surface and inland waters are covered by a layer of snow, or snow and ice; air temperatures are below freezing; and the intensity of direct solar radiation is low, reaching zero in Arctic regions for part of the winter. During this period the process of photosynthesis is much reduced, plant growth is at a low ebb, water-soluble products in the soil and in organic matter are held stationary or moved very slowly, and chemical breakdown of minerals is essentially nil. Animal life of both low and high orders must live largely on stored and imported supplies. Vapour pressures in the atmosphere are low, and at low temperatures (below –30°C) atmospheric moisture is in the form of ice crystals, with distinctive chemical adsorptive characteristics. The distinctive vertical temperature gradients often encountered during northern winters may inhibit the mixing and dispersion of air masses. The exchange of oxygen and other chemicals between the atmosphere

and the soil or water bodies is inhibited. Under such conditions, airborne, waterborne, or precipitated pollutants have a distinctly different behaviour and course of action than they do when liquid water is present throughout the year.

In a typical Canadian spring, much of the winter's precipitation is melted within a short period and runs off or soaks into the ground rapidly, causing a marked dilution of the mineral and organic concentration of normal drainage waters. At the same time, this run-off carries with it several months' accumulation of pollutants that have settled from the atmosphere, which have been concentrated by the progressive sublimation and melting of the snow. This concentrated dose of pollutants may thus be released into the soil and streams just at the time of biological germination, budding, and accelerated growth, and at a time when normal waterborne mineral and organic buffer substances are at their lowest concentration.

The geological history of Canada is responsible for a distinctive situation with regard to the behaviour and dispersal of pollutants. The retreat of the Pleistocene ice sheets left large parts of Canada covered with newly deposited surface materials—moraine, glacial lake deposits or fresh sediments laid down in temporary seas—and left other large parts scoured nearly bare of soil and weathered material. Over much of Canada the drainage system was disrupted and disorganized. As a result, Canadian soils are typically young, containing mostly fresh and unweathered mineral grains; thousands of square miles of rock exposures are relatively fresh, unleached and only slightly oxidized; and there are myriad lakes connected by very small streams and with an exceedingly slow flushing rate. Soluble or suspended chemicals washed into lakes and muskeg, or onto the surface of the permafrost beneath the summer melt layer, may become trapped for long periods and accumulate. Over much of Canada, also, the natural biota are recent immigrants. Many species of both aquatic and terrestrial vegetation and animal life are pushing northward or expanding from centres where they have established a foothold, and territories and inter-specific relationships are evolving rapidly. Under these conditions, many chemical pollutants have a greater relative opportunity to become incorporated directly into soils and organic materials than they would in parts of the world where the land surface is geologically older and thus chemically more stable and resistant, or where the natural drainage is more systematic and less interrupted; and the potential biological consequences may be different than they would be in areas where the ecosystem is more mature.

Over about half of Canada the surface and soil waters are perennially acid, because of the slow drainage rates in glaciated and permafrost regions and the low temperatures which lead to accumulation of partly decomposed organic matter. The micro-organisms which helped to produce and are adapted to this situation will have a selective reaction to pollutants from energy activities.

For these interrelated reasons, many of the environmental effects of energy use observed in southern temperate regions cannot be assumed to apply to Canada. Some effects may be much more severe than in warmer, unglaciated regions, and others may be less so; and there may be some aspects of energy use that cause negligible disturbance in other parts of the world but have important consequences for the Canadian environment. In the more northerly regions, the contrast with

temperate conditions is more marked, and by-products of energy use such as waste heat, water vapour and carbon-dioxide from even modest energy use can cause severe adverse local disturbances in the environment. It is clear that environmental policies and regulations that have been found effective in other regions may not necessarily have the same effects on the Canadian environment. It is apparent also that an understanding of the physical and biological processes operating in typical Canadian environments, and the effect of energy activities on these, is necessary if the environment of Canada is to be protected from the adverse effects of energy production, conversion and use.

The "Geographic Handicap" of Living Downwind and Downstream

The most populous area of Canada is situated geographically so that at times it lies downwind from a heavily industrialized and pollution-producing area of the United States, and it shares a common watercourse with it. The air and water drainage systems passing that part of Canada where environmental disturbance is most of a problem are therefore at times already disturbed or "loaded" to a greater or lesser degree by our southern neighbour. The environmental protection measures taken by Canada to benefit our most heavily industrialized area must also take account of, and where necessary counteract the effect of, activities outside Canada that affect the Canadian environment. The area is also the greatest user of energy of any part of Canada, and thus our national energy policy must be designed to apply directly to this environmental situation without unduly handicapping the use of energy in other parts of the country.

Shelter for Both Ships and Pollution

By an accident of geography, Canada is blessed with protected inland seas and deep embayments on all three coasts. Our harbours and coastal cities, with their associated industrial complexes and large movements of petroleum products, are all on sheltered waters. In such waters circulation and flushing is restricted and the effects of pollution or waste heat are less readily distributed and longer lasting than they would be in more open waters. These same sheltered waters are frequently biologically prolific, and the adjacent shorelines most attractive for habitation or recreation. Thus any pollution originating in the harbours or coastal cities is likely to be concentrated where it will do the most environmental and economic damage.

Although there is no justification for allowing pollution from any activity if it can be avoided, it nevertheless could be argued that from purely environmental considerations, industrial operations producing heated water or with a risk of polluting would be better sited in exposed locations, on high-energy seacoasts where there is maximum mixing and dispersal of water masses, than in sheltered waters. It has been proposed that certain major industrial facilities, such as supertanker ports, or nuclear power stations, should be sited in such places. Canada appears to have few easily accessible potential industrial sites of this nature.

It therefore appears that if we wish to ensure adequate protection of the coastal and marine environment of Canada and still maintain the vigour of our port

industries and coastal commerce, our environmental and energy policies must be able to cope on a routine basis with a situation approaching the worst case in terms of environmental sensitivity and potential damage.

The Asset of Low-Cost Power, Space and Water

The availability of large amounts of power at relatively low cost, plus ample supplies of clean fresh water and land space, has enabled Canada to develop energy-intensive industries, such as paper manufacture and aluminum smelting, to a degree that would not otherwise have been profitable. These industries form an important part of our national economy; individually they have in the past sometimes been disturbing to the local environment, but they have usually been in isolated locations and the regional environment has been able to absorb the impact with little net damage. With modern awareness and technology the undesired effects on the environment can be eliminated, but these industries will still require large amounts of space, fresh water, and energy. It is misleading to compare directly Canada's use of energy for industrial purposes with that of other countries and make conclusions on the relative efficiency and potential effect on the environment, for one of Canada's unique assets is the ability to sustain energy-intensive industries without serious degradation of her environment.

The Frontier Attitude

Most Canadians, whether newly arrived in the country or many generations native-born, possess to some degree a frontier attitude toward their land. This attitude results in a characteristic ambivalent posture toward the environment. On the one hand nearly all Canadians value and love their country because of its wildness, and in some way get satisfaction from feeling that "unspoiled Nature" is just two steps from their front door. In fact, of course, a citizen of London, Ontario, or Brandon, Manitoba, has to go a long way, and a Prince Edward Islander has to leave his province to find a part of Canada where man has not altered the landscape; but rural surroundings where natural processes are important or dominant are quite close to any Canadian, no matter where he lives. Nearly all Canadians, even those in the most crowded parts of our cities, have a personal view, based to some degree on their own experience and observation, of the contrast between the "natural" and "civilized" face of Canada. Even if they never visit undeveloped areas, and are determined to keep Nature at least two steps away from their door, most Canadians have a desire to protect what they perceive to be the "natural" character of their country. On the other hand these same Canadians may look upon the wilderness as something to be tamed, something that is of little value unless it is put to use by man. The economic and physical survival of early Canadians both native and immigrant, depended upon the ability of her citizens to "cope" with Nature; and whether descendents or not, modern Canadians seem to have inherited a desire to leave a mark on Nature, to chop a tree, dam a brook or clear a path. The conflict is apparent in the reasons why the average Canadian desires or uses a summer cottage, a snowmobile, a fishing rod, or even a camera.

To "tame the Wild West" was a catch phrase for North Americans for two generations. To "open up the North" is accepted by many Canadians today as a national duty, and our destiny; even though what the opening means and whether the North needs it is not clear. It is perhaps significant that our national symbol is the beaver, an animal distinguished above all for his ability to rearrange his local environment through industry and construction. That he also causes a lot of destruction, and periodically makes his home uninhabitable so that he has to abandon it and move on to start afresh in unspoiled territory, is forgiven in our admiration for his industriousness and his engineering ability. And yet, in admiring the beaver, we are feeling sympathy with Nature.

These contradictory feelings, found not between different sectors of the population but within typical Canadians of all economic levels and social backgrounds, may have an important bearing on the acceptability of environmental control measures connected with energy use. Accustomed to hydroelectric power which is clean at the point of application and as far as he can see obtained "free" by harnessing Nature, taught to look on engineering works as entirely creative, so that a storage reservoir is regarded not as a dislocation of the ecology but as a newly-made attractive recreational area in an otherwise undeveloped valley, harbouring a nostalgia about the romance of the steam locomotive puffing black and white clouds of history as it tied the nation together, and feeling that in some undefined way the nation's vitality is demonstrated through giant construction projects, the average Canadian is apt to be hard pressed to sort out his feelings about energy use and the environment. Clean Nature is all about him; pollution is someone else's problem. More than the citizens of many other countries, Canadians have had the opportunity to push their energy-induced environmental problems out of sight—into a distant valley where few people or apparently no one lives, or down the river—and they have done so to date with few consequences that they recognize. Many of us still have the feeling that the land *ought to* be big enough to reduce our own activities to insignificance and overcome and counteract our environmental messiness without action on our part, even though we know that this is no longer true. At the same time, sympathy with Nature is a fundamental part of the Canadian character and outlook, and citizens have demonstrated repeatedly that they are willing to pay to preserve their environmental values. To a large degree the effectiveness of our energy and environmental policies will depend upon how they enable Canadians at large to reconcile their own contradictory feelings toward the land in which they live.

The Influence on Canada of Foreign Environmental and Energy Policies

Canada is a "middle power", and its energy dealings, domestic or foreign, are not of sufficient magnitude to have a controlling influence on world politics or world trade. Our energy resources, while large in Canadian terms, are insufficient to have an important effect on the energy problems of our chief foreign customer, the United States. They are, however, sufficient to ensure that prices for the main energy commodities in Canada will be influenced by world prices, and these prices

are to an increasing extent influenced by the environmental problems and policies of the major petroleum importing and producing countries. Canada's domestic environmental policies are not likely to have much effect on the international energy scene; but because of the vulnerability of our long coastline and Arctic areas, because much of our population lives in an international region of pollution generation, and because in many parts of the country we presently depend for energy on imported fuels (coal and oil) that must be produced and transported under the environmental regulations of other nations, Canada has strong reasons to work actively toward the development of international environmental law as it applies to energy activities. Canada has therefore actively supported and endorsed Principles 21 and 22 of the United Nations Declaration on the Human Environment, which proclaim that states have the right to exploit their own resources and the responsibility to ensure that their activities do not cause damage to the environment of other states or to areas beyond the limits of national jurisdiction (Principle 21), and that states shall cooperate to develop international law regarding liability and compensation for environmental damage to areas outside the jurisdiction of the states where the damaging activity originated (Principle 22).

Canada is thus in the situation that it can consider the environmental aspects of its energy policy in terms of basically domestic issues, but the economic aspects may well be influenced by the environmental policies of other countries.

The International Subsidy

Canadians benefit, both economically and in quality and range of available goods and activities using energy, from partial integration with the United States market and marketing system. Energy-using equipment and processes developed to conform with United States environmental standards are likely to be used in Canada. Our popular norms for the cost and convenience of energy are basically those of the United States, and we would not now be enjoying them had we not had the advantage of the large investments in fuel production and marketing, and appliance development and manufacturing, made possible by the much larger United States demand for coal and petroleum. Our popular concerns about damage to the environment from energy activities, also, come largely from United States experiences and concerns. Although most Canadians are aware of differences between the Canadian and United States situations, it is likely that Canadian opinions about the relationship of energy activities to environmental quality will continue to be strongly influenced by the publicity given to the issue in the United States, and by the success or failure of United States policies.

If the costs of energy rise in the future, pressures are likely to increase for even greater integration of energy production and marketing systems, and for uniformity of environmental guidelines and policies. The availability of funds needed to develop and market new energy resources in Canada will be strongly influenced by the degree of integration of U.S. and Canadian energy markets and the environmental concerns and actions of both countries. Canada's energy and environmental policies must therefore take into account the environmental as well as the economic aspects of the energy policies of the United States, and the effect of those policies on business and private attitudes and actions in both countries.

The Problem of Canadian Heterogeneity

The geographic and demographic diversity of Canada, and the varied background and range of cultures of its citizens leads to a wide range of expectations and differing priorities regarding energy use and the environment. Our heavy dependence on energy-consuming items that are designed or produced primarily for other countries with different environmental problems and acceptable norms also adds complexity to the requirements and the applications of energy policies with respect to the Canadian environment. Such heterogeneity calls for a wide range of solutions to energy-environment problems.

Chapter 3

ENVIRONMENTAL QUALITY AND THE ENVIRONMENTAL GOALS OF CANADA'S ENERGY POLICY

It is important to distinguish between the quality of the environment and the characteristics of the natural environment itself. The natural environment is the product of the geology and climate of the region, the geological and climatic history, and the history and stage of development of its ecosystem. The range of natural environments found within Canada is very great. One need only compare the lush rain forests of Vancouver Island with the windy tundra of Keewatin, or the grasslands of Alberta with the Bay of Fundy tidal flats, or the rich farmlands of the Niagara peninsula with the bleak uplands of Baffin Island to realize that there is not a typical or average Canadian environment. This diversity of natural environment, based ultimately on the interaction of climate and geology, is fundamental to the character of Canada, and it contributes importantly to our sense of identity and our strength as a nation. Yet each of these environments, no matter how different they may be from one another, can be of high or less high quality; can be healthy or less healthy for the species, including man, that inhabit it; can be conducive or in various ways inhibitory to attainment of the full biological or cultural potential of the region. The quality of the environment will be determined largely by the degree to which the composition of the air and water in the region is maintained and renewed by natural processes, and by the extent to which the development of the landscape and the functioning of the biological processes are free to proceed in harmony with the climate and the geology.

Despite—or perhaps even more because of—the variety in natural surroundings, climate, and biological activity, Canadians in all parts of the country have a right to an environment whose quality is basically healthy, and in which the ecosystem, including people as part of it, can operate in a balanced manner.

Contrary to what may sometimes be assumed at first thought, a high quality environment does not imply or require an environment unchanged from that which was present in Canada before human settlement, or a primitive situation in which man is absent or insignificant. Well-managed farms or industries can operate in, and indeed contribute to regional environments of as high quality as "untouched" natural land. What is important is not the presence or absence of human impact, but whether human activities are carried on in harmony with Nature. In this process, Man's use of energy and disposal of its waste products are critical.

The Government of Canada has established national objectives for environmental quality which apply to all parts of the country. Provincial and municipal governments have supplemented these with guidelines for particular areas or problems. If these objectives and guidelines can be met and maintained, Canadians will be able to enjoy, and to continue to enjoy, a healthful and satisfying physical and biological environment no matter in what part of the country they may live. Our environmental policies must strive to bring this about and provide the incentives or guarantees that safeguard and maintain the quality of our environment. The national energy policy, as such, cannot set up detailed environmental regulations to be applied indiscriminately in all of Canada, but must set forth a consistent philosophy and set of objectives, compatible with the national environmental objectives and regulations, concerning the relationship between the benefits of energy production and use and the impacts on the environment of energy activities. Under this philosophy and set of objectives, detailed policies or rules appropriate to specific regions or activities can be applied.

A successful national energy policy must therefore integrate environmental factors with the economic and social factors to provide adequate energy for all Canadians in a natural and social environment that is and continues to be acceptable, productive and satisfying in every part of Canada.

The basic goal of the national energy policy with regard to the natural environment should be that of supporting or facilitating environmental practices which will achieve an acceptable environment in every part of Canada, and then maintaining that quality of environment regardless of the amount of energy produced or used. To achieve this goal will require that, for at least the next three decades:

> The total mass of transient or short-lived air pollutants delivered to the atmosphere in any given part of Canada shall not exceed Canadian and international air quality standards;
>
> The addition of persistent or cumulative pollutants to the atmosphere, waters and soils be known and firmly controlled;
>
> The survival and natural range or distribution of Canada's native flora and fauna, including species found along our seacoast and in our territorial waters, should not be endangered by energy activities, except where with the knowledge and participation of biological and environmental authorities the consequences are weighed beforehand and a decision to proceed or continue with the energy activity is made by agreed procedure;
>
> Canadian landscapes and coastal areas will not be significantly disturbed by energy activities, except where such change is planned and controlled, with provision for restoration or public compensation;
>
> Release of radioactivity or radioactive materials should not exceed amounts presently anticipated and internationally accepted as being of insignificant threat to biological activity;
>
> The discharge of oil and related hydrocarbon products into the ocean, either directly, by flushing from the land via rivers, or by precipitation from the

atmosphere, will be reduced from what it is at present, and held at a rate that does not exceed the capacity of the oceans to degrade and assimilate the material received; action must be taken to prevent cumulative build-up of persistent compounds; and the statistical risk of unexpected or catastrophic discharge for any given amount of petroleum products transported on or under the ocean, must be considerably lessened;

In any local area, pollution or adverse effects from any energy activity will not endanger human health or, in the light of the best technical knowledge available, have an important influence on the functioning of the ecosystem.

Chapter 4

ENERGY AND THE IMPLEMENTATION OF ENVIRONMENTAL POLICIES

The Feasibility of Maintaining Environmental Quality in a High-Energy Society

Although many of the most serious undesired impacts on the natural environment caused by energy activities do not become important until a certain threshold tolerance of the environment is exceeded, and although the total and cumulative effects in some areas are increasing very rapidly with increasing energy use, an analysis of the nature of these impacts, and the means of counteracting them, shows that simple reduction or restriction of energy use per se is not an effective way to reduce or control unwanted changes in the environment. It would be impossible to maintain a viable Canadian economy and to operate Canadian society as we know it with energy consumption reduced so low that environmental changes were negligible regardless of how the energy was produced or used. What is required to maintain environmental quality is therefore not primarily restriction of energy use, but rather control of the environmental effects of energy production and use.

Present information suggests that it will be possible, with presently known or immediately foreseeable technology, to meet the goals and standards described in Chapter 3 for environmental quality, and still produce sufficient energy in the variety required to meet Canada's expected needs. It appears possible and feasible for this to be done without causing drastic changes in the pattern of energy supply or method of use. However, to achieve these goals and maintain the desired quality of the environment in Canada it will be necessary to have:

National and international agreements on specific aspects of environmental quality and practices;

Impartial and accepted monitoring networks and analysis procedures;

Tough legislation and enforcement;

Public information, discussion and participation in energy-environment decisions;

An economy that can sustain the increased short-term and middle-term costs of converting to environmentally acceptable methods of energy production and use without placing undue hardship on specific sectors of the society.

Failure to achieve a satisfactory quality of environment in the near future, while energy use increases markedly, will invite much greater long-term costs and national hardship, and may lead to a permanently handicapped country.

National and international objectives and standards for environmental quality may change in the future, with improved knowledge of the environmental consequences of various activities, and with increased understanding of the characteristics and behaviour of different environments. They will also be affected and possibly modified by changes in social values and economic conditions. From present information, however, it appears that the most stringent environmental standards likely to be set by Canada or international agencies could be met without causing a fundamental change in Canada's overall use of energy, although compliance could cause significant local adjustments in private or public activities and in some areas the cost and technical difficulties might increase considerably.

In other words, from the point of view of the production and use of energy, it is technically feasible for Canadians to have as clean and unstressed a natural environment as they are willing to discipline themselves for and pay for. It appears unlikely that the additional cost of meeting foreseeable environmental standards will by itself cause a fundamental change in the trend and pattern of use of energy.

The Need for Improvement in Knowledge and Management

Despite the fact that it appears possible with presently known technology to prevent undesired environmental effects while meeting Canada's anticipated need for energy, there is room for much improvement in the knowledge and techniques of environmental management of energy activities.

Shortcomings

The following are examples of improvements needed in knowledge, practice, and attitude:

Many present or planned *environmental control techniques* are inefficient modifications to existing polluting or damaging techniques, or are supplementary processes. The obvious advantages of designing to avoid undesired environmental effects are ignored or neglected for a variety of reasons, including habit and ignorance;

Industrial management tends in many cases to look upon environmental protection as a nuisance and an extra cost, rather than a long-term benefit, partly because environmental control may not advance the immediate competitive position. As a result, management expertise in the environmental field is not rewarded;

Mechanisms are non-existent or poorly developed for *relating or transferring,* in advance of or simultaneously with energy development, the *benefit* that one sector of society receives from energy use to other sectors which incur costs or disadvantages because of environmental change;

Despite the fact that environmental goals can be achieved using present technology, there are still important *technical gaps*. For example, in removing

sulphur or sulphur compounds from particular fuels, no satisfactory large-scale process of environmental control is yet known, and until an effective and economical one is found, those fuels are handicapped as a Canadian resource;

There are areas where the *subtle and cumulative effects* on the environment and on biological processes, including human health, are insufficiently known to set environmental standards or pollution tolerance levels with confidence. This applies particularly with regard to some dispersed metal compounds, trace elements, and newly created carbon compounds;

There is room for much development and imagination in the concepts, methods, and financing of *sequential land use* in the Canadian context;

Methods of incorporating *long-term intangible environmental benefits or costs* into economic analyses, or of relating the various degrees of qualitative importance that different segments or groups give to different aspects of environmental quality at different times need to be refined and improved.

Objectives

A comprehensive and balanced program of scientific research, development of technology and managerial methods, studies of the possibilities and efficacy of various legislative and enforcement options, and international action is needed, in order to:

Improve the long-term economy and efficiency in making available and using adequate energy without compromising the desired level of environmental quality;

Achieve the best present and long-term management of Canada's energy resources; and

Ensure that the qualitative and intangible aspects of environmental control with respect to energy use are taken into consideration with participation by the various sectors of Canadian society.

Results

Such a program should lead to the development and implementation of:

A coordinated and effective program of land use and land management, together with its equivalent for offshore areas;

A better understanding of the biological, physiographic, hydrological, atmospheric and marine processes affecting Canada's environment and their interaction; and application of that knowledge to regulatory guidelines and standards;

A better understanding of the economic, social and environmental factors that influence demographic trends in Canada, and methods of coordination between the various levels of government whose policies influence those trends;

Improved techniques to achieve environmental protection at lower cost without decreasing the efficiency of energy use, increasing waste disposal problems, or transferring the pollution elsewhere;

Under the national guidelines and standards, practices for environmental protection appropriate to the various regions and situations in Canada;

International agreement and legislation governing practices that affect the quality and contamination of the oceans and atmosphere, and an international environmental monitoring and enforcement system.

Urgency

It is essential that action be taken immediately, at all appropriate government levels and by industry, to implement such a program. With every passing year the problem of achieving environmental quality becomes more difficult and the cost becomes greater.

Government Responsibility and Regulation

The federal government has established national objectives for air and water quality for all of Canada, and together with the provinces is developing guidelines to reduce or control disturbance of terrain, or displacement or destruction of wildlife and indigenous vegetation. Within these national objectives and guidelines there is scope for a variety of choices of behaviour and for trade-offs between activities that have different individual and combined environmental impact. Many of these choices will involve energy activities. Canada's energy policy must facilitate the making of these choices so that the national economy remains strong and diverse, the natural resources are used to achieve the greatest economic and social benefit, while at the same time the quality of the environment is maintained above the established acceptable levels.

Factors

Although the fundamental purpose of environmental regulations and standards must be to achieve and maintain a desired quality of environment and not to regulate human or industrial activities, it remains true that protection of environmental quality can in most cases only be achieved through prevention or control of polluting or disturbing activities. From the point of view of Canada's energy policy, this control should be as flexible as possible, always ensuring that national objectives and standards of environmental quality are not violated. Such control or regulation should take into account the following:

The provincial governments, which control natural resources and many aspects of industry, must be able to determine the activities that best meet their objectives;

Trade-offs in the public interest, between economic, social and environmental objectives will vary in the short, medium, and longer terms, and will be different in different regions because of variations in total environmental stress or pollution load and differences in the nature and behaviour of the regional

environment. They also will vary from time to time with changes in the economy or social tastes, as industry develops or changes emphasis, and as new techniques are introduced. Such trade-offs need not in any way compromise the environmental objectives, but may determine the methods of combinations of activities by which these objectives are reached. There may be some who maintain that Canadians do not need to accept trade-offs between environmental improvements and economic objectives, but any activity of mankind, or indeed of any component of any ecosystem, results in trade-offs between related or dependent activities. Trade-offs in the public interest can only be eliminated by eliminating mankind. Provided that national objectives of environmental quality are not violated, environmental controls must not be so inflexible that those developed to protect the environment in one region prove to be an unnecessary handicap or environmentally self-defeating in another;

The true net economy and long-term benefits accruing from *proper design of equipment and techniques* to avoid undesired environmental changes, as opposed to palliative remedial measures to counteract faulty design or methods; and consequently the desirability of encouraging investment in environmental control before construction or manufacture of energy-using facilities or equipment. Such investment and attention in advance to environmental effects will nearly always be cheaper, more effective, and give longer-lasting protection than a supplementary process designed to clean up an environmentally unacceptable technique;

The advisability, where it is not possible to design or prepare for environmental control in advance, of instituting *graduated implementation of environmental control.* In some cases this graduated regulation will be based on the "best practicable technology" so that as knowledge and methods improve it will be possible to tighten the regulations. In other cases graduated regulation may allow activities to continue "to pay their way" and the economy remain productive while ultimately achieving lasting environmental quality. Such practices may be advisable where present technology is cumbersome or expensive and there is reasonable hope of near-term improvement, and it may be necessary with respect to older plants, or in developing regions or economically depressed areas where stricter regulations would stop operations completely. But graduated implementation of environmental control must be applied with great care to ensure that the incentive for improvement is not lost, and to avoid discrimination and the development of pollution centres that can only lead ultimately to increased hardship and greater long-term costs;

The need to weigh the direct economic savings resulting from standardization of energy-consuming capital goods or facilities against the *true net cost of such standardization,* in terms of resource use, and social, convenience, and over-all environmental aspects. To the argument that in the scheme of mass production it may be impractical to have a range of different types of "standard" equipment designed for various regions, it should be pointed out that this has rarely proved to be the case if there is an economic advantage to be gained

by diversity, or if a regulation demands it; but if this should be so (e.g. if car manufacturers insist that they cannot make vehicles designed for different environmental situations), then it should be known to what extent the advantages of conformity may be offset by higher future costs, inefficient use of resources, and negligible environmental benefit in areas other than that for which the equipment or process was designed. In such cases, perhaps, equivalent money could better have been spent on different and more effective environmental protection.

The desirability of adjusting local environmental control to temporal variations in environmental conditions. Because of the continental climate of much of Canada and the wide seasonal differences in the characteristics of the atmosphere, surface waters, ground conditions and biological activity, there are in many places wide variations, from one time to another, in the tolerance of the environment to stress from energy activities. With proper knowledge and planning it may be possible to take advantage of these variations, and achieve economy of operation without endangering environmental quality or compromising the national objectives. Performance specifications for energy activities should be flexible, where feasible, and coupled to the condition of the natural environment. Examples of such flexible practices, many of them already in use in Canada and elsewhere, are:

Municipal ordinances which restrict or in extreme cases shut down certain polluting industries during periods of sensitive atmospheric conditions;

Arctic oil-fired power stations that switch to more expensive stand-by natural gas supplies during periods of atmospheric temperature inversions;

Cooling water re-cycled during periods of low stream flow whereas more economical once-through cooling may be used during normal periods;

Prohibition against idling motor cars on the street in northern towns in winter on calm days, but allowing it otherwise;

Prohibitions against using tracked or wheeled vehicles on the tundra during the summer thaw season, on oil exploration activities.

Restrictions against peak-load drawdown in hydroelectric reservoirs during fish-spawning periods.

A further benefit of providing for flexibility of environmental control with varying environmental conditions rather than enforcing uniform behaviour to cover the worst case, is that a flexible operation leads the operators, management and the man in the street to become aware of the connection between energy activities and environmental processes, and helps develop a general environmental consciousness;

The desirability or need to implement *increased environmental protection in areas of high environmental stress or special sensitivity.* Clean air objectives have been proclaimed for Canada. With the present state of our knowledge

it is believed that the "acceptable" level so proclaimed will prevent ill effects to human health or damage to plants, animals or vegetation. In areas of high environmental stress it may be necessary to tighten these requirements upward locally. Similarly, it is not unlikely that there will be locations where the streams or soils of Canada will naturally have a composition or physical state such that they are relatively sensitive, in comparison with other parts of the country, to developing a toxic or unstable character as a result of the effects of energy activities. In these areas also it will be necessary to have stricter environmental controls. We know very little about how to assess, or to manage, the offshore and sea-floor environment, in terms of carrying on industrial or energy activities and still protecting the environment from damage. By the time we are aware of the effects on the marine environment the damage may be considerable. We have at present little means of control except to stop operations completely, as was done in 1971 in the Straits of Georgia. But as our knowledge grows, it will be possible to establish norms of acceptable operations, and to recognize and define more accurately sensitive or critical areas where specific tighter control is needed, including areas where all industrial or underwater operations should be prohibited.

The cumulative and synergistic effects of different aspects of the environmental impacts of energy activities may, in the long run, be among the most difficult to deal with in maintaining acceptable environmental quality while energy production and use increases. Waste heat and some stable compounds of combustion, metallic elements and persistent artificial organic substances released from impurities or additives in fuels may appear innocuous or insignificant at present, but conceivably may accumulate until their local or global environmental effect is serious. Once they have accumulated to this level, their treatment or neutralization may be very difficult.

The synergistic effect of some combinations of products from energy activities is well known. A familiar example is the enhanced undesired effects when nitrogen oxides and particulate matter occur in combination compared to their separate impacts. There may be many examples of "pollution synergism" whose importance is not yet recognized.

A management problem arising from both cumulative and synergistic effects of energy activities is that the addition of new or intensified energy activities in a given area may lead to environmental impacts much different from those experienced previously, or expected from the new addition alone. Protection of environmental quality may require an activity, which was harmless or permissible by itself, to be changed when another activity, also permissible by itself, is started in the area. The national energy policy and environmental control mechanisms must find the least disruptive way for this to be accomplished.

One Set of Rules, or Many?

Some difficult decisions lie ahead, for policy-makers and for individual Canadians. Almost all will agree that the quality of the environment must be maintained. But the Canadian political and regulatory system tends to take little account

of Canadian demography and its relation to the variations of natural processes in Canada. Part of the cost of environmental protection is not technological but the cost of achieving a uniform objective in a varied land.

Should rural areas, with little potential for creating environmental disturbance that exceeds the national objectives, and with their limited financial resources and economic handicaps, be subjected to the same controls as large urban areas? Should a small isolated town, with a limited tax base and little likelihood of adversely disturbing its regional environment, be required to meet the same standards in its local power station as a big city with its multiple stations, regional grid and economic strength? Should the dweller in that town pay to have city-type controls, even though from the environmental point of view such controls may not be needed or effective in this situation? Should communities in the far north, operating on government subsidy and welfare payments, be controlled as if at any time they expected to meet the environmental challenges of Toronto?

But if someone or some area is to be given special treatment, where is the line between special and non-special to be drawn? Take, as one example among many, the need for environmental control of motor vehicles. That the farmer in central Manitoba has no need, from the point of view of preserving environmental quality in his home area, to have his car equipped to meet all the standards imposed for Toronto is logical; it is also logical that if he were to drive in Toronto he must expect to conform to Toronto standards. But who should see to this? Should the governments, provincial and federal, conclude that all cars are liable to go anywhere, and regulate accordingly for the worst condition, thus guaranteeing that extra fuel will be used for no transport purpose and extra expense will have to be paid by some who can least afford it and will get no direct benefit from it? We do this with some problems (e.g. aircraft safety) but not with others (e.g. quality of milk). Should the Manitoba farmer himself weigh his likelihood of going to the city and decide whether he should buy a "city approved" or a "country only" car? That's what he does when he buys his overcoat. Where, for pollution control purposes, does a town become a city? Some big cities are far cleaner, environmentally, than some small towns.

There are no simple answers to these questions. One conclusion that emerges is that if Canadians are to continue to produce and use energy in the amounts and for the range of purposes that they have been in the habit of doing and apparently desire to continue, and if they still want to achieve optimum economy and efficiency in their commercial and private activities while maintaining the quality of the environment in all respects above the national objectives, they will no longer be able to use the same equipment and techniques in all parts of the country. One of the prices to be paid for an optimum economy plus a clean environment will be the loss of the simple freedom to do things in just the same way in all parts of Canada.

Conversely, uniformity of practices in a clean environment will mean greater costs and in some areas, inefficient practices.

Despite the logical advantages of flexibility in practices to achieve and maintain environmental quality under different environmental conditions, it is also obvious that environmental regulations and energy policies with respect to the environment must be consistent, clear, and free from ambiguous or subjective interpretation, no matter where they are applied. No purpose is served if in the

name of flexibility, practices may develop which run a risk of compromising the quality of the environment. A separate regulation for every condition or activity provides no control at all.

Legislation and enforcement of environmental regulations at all levels of government must provide for this complex situation. To be effective, such legislation must concentrate on the quality of the environment and the influence of any and all activities on that quality, rather than on the activities themselves. To be realistic, it must take into account the quantity and magnitude, as well as the nature, of those influences, and, in the last analysis be prepared to control the quantity of disturbing activities.

The basic definitions and objectives of environmental quality must be nationwide, and independent of climate, demography, or industrial activity. To ensure that the desired quality is maintained in all areas, with reasonable economy and efficient use of resources, Canadians will have to adapt their energy activities, as they do all their other activities, to the particular environmental situation in which they undertake them. No longer will it be possible to take for granted that we can produce or use energy, anywhere in Canada, by methods or equipment designed to meet the environmental standards of other countries, unless those standards are for the most extreme or critical conditions to be met within Canada, in which case Canadians in the rest of the country, and at other times or seasons, may be paying a penalty with no significant benefit to their environment. Ironically, it may well be the Canadians in the hinterland areas, who by and large are less able to afford it and whose natural environment is less endangered by energy activities, who will pay the highest price for protection of the Canadian environment.

Chapter 5

THE EFFECTS ON THE ENVIRONMENT OF ENERGY ACTIVITIES

The use of energy by man for industrial or social purposes is merely a concentration or acceleration of processes that proceed, with varying degrees of effectiveness, in Nature without man's intervention. As the natural environment, and life itself, is a product of these and other energy processes, the concentration and acceleration by man of selected energy operations has an intimate relation to, and effect direct on, the physical and biological functions of the environment. Because the natural environment is the sum and result of a complex of natural dynamic processes that proceed at a gradually evolved scale and rate of energy exchange, most of the effects of man's energy use disrupt these processes and thus are disruptive to the environment. The magnitude of the effects are directly related to the degree of concentration and acceleration of man-induced energy processes compared with those in nature.

The following are brief descriptions of some of the ways in which energy production and use in Canada does or may affect the natural environment. Some of these effects are purely local; others are worldwide in their influence. Some while dramatic in human terms, are transient and short-lived, while others may be persistent and cumulative. There are still other products or influences of energy use whose significance and effect on the environment are not known.

Effects on the Global Environment

There has been much speculation, and several tentative attempts at measurement, of the effects of human activities on the Earth's environment as a whole. Certainly, products resulting from the production and use of energy by man can be detected in nearly every part of the planet, including the oceans and high in the atmosphere. It is obvious that human activities, made possible through extensive use of energy, have affected the vegetation and landscape of a significant portion of the land areas of the world, and that the sediment load and chemical composition of many major drainage systems has been changed. Despite these apparent changes, the evidence to date is insufficient for conclusions on the quantitative significance of the influence of man on planetary environmental processes. There are some areas, however, where energy activities have affected the global environment in ways that have altered, or potentially could have an important effect in the future, on its quality. Five of these, which have had considerable attention, are noted below as examples.

Oil in the Ocean

Some oil can be found on the surface of nearly every part of every ocean. It comes from a multitude of sources around the world. Approximately two million tons of heavy petroleum products are introduced into the oceans each year from ocean shipping, oil-polluted rivers, port and industrial activities, offshore drilling and oil production. An additional amount, unknown in quantity but possibly equally large, is deposited on the ocean surface from the oil-polluted atmosphere.

Despite numerous detailed observations, mostly in near-shore areas, and considerable research on the gross consequences of major oil spills, little is known about the regional or cumulative effects of petroleum products on marine life in the open ocean. However, known dangers include the direct kill of organisms, particularly micro-organisms and plants which determine primary productivity and help regulate the planetary oxygen supply; and the incorporation of petroleum molecules and associated chemicals into organisms at several levels of the marine food chain, resulting in reduced vitality, reproductive failures or cancers. The danger cannot be entirely dismissed that a persistent but small film of oil on the ocean may ultimately be disruptive to the entire marine ecosystem, with consequent effects on terrestrial life.

Oil in the open ocean tends eventually to collect at areas of convergence, or be washed ashore, with consequent concentrated effects on biological processes and fishing or recreational activities. The Sargasso Sea and the no-longer-clean beaches of Bermuda are examples.

Carbon Dioxide in the Atmosphere

The weight of present information indicates a considerable increase in carbon dioxide in the atmosphere in the last several decades. The relation of the present concentration of CO_2 to that in previous centuries or past ages is not known, but the documented rate of change in the past two decades is such that the concentration cannot reasonably be presumed to have been changing in such a manner for longer than half a century, i.e. since the time of a marked increase of burning of fossil fuels. It is therefore reasonable to conclude that the increased emission of carbon dioxide by burning fossil fuels in the past several decades has not been completely compensated for by natural processes of absorption of CO_2, and that man and his energy activities is partly or largely responsible for this change in the global atmosphere. If present apparent trends continue the CO_2 content of the atmosphere may increase another 20 per cent by 2000 A.D.

The environmental effect of an increase of carbon dioxide in the atmosphere is not clear. Carbon dioxide absorbs solar and infrared radiation, and so an increase in concentration will increase the diffusive resistance for long-wave radiation and lead to a warming of the surface and lower atmosphere (the so-called greenhouse effect). However, this effect may be at least in part offset by increased evaporation from the oceans with increase of high-latitude precipitation, and associated increased reflectivity of the planet and its atmosphere with consequent decrease of incoming heat. It is also difficult to dissociate the effects of carbon dioxide in changing the radiative and reflective properties of the atmosphere from

the changes due to variations in high-altitude dust content, some of which are due to human actions, such as fuel combustion (see below) and cultivation of land. Although it is conceivable that the effect of man-induced CO_2 in the atmosphere could at any time be overwhelmed by the atmospheric influences of major volcanic eruptions, it is reasonable to expect that continuation into the next century of continuous CO_2 emissions from fossil fuel combustion at the present accelerating rate could lead to a long-term warming of the earth's surface.

The amount of warming that could be tolerated on the earth's surface, and the rate of warming that could be accommodated without significant disruption of the world ecosystems including man, is not known, but may possibly be quite small. The worry is that such a change, if it approaches a critical condition, may in human terms be irreversible and uncontrollable.

Combustion Products in the Stratosphere and Troposphere

The engines of high-altitude aircraft inject particulate matter from fuel combustion directly into stratosphere and troposphere. Although in absolute terms the amount is minute in comparison to the volumes of the atmospheric envelopes, the relative change of concentration of particulate nuclei and certain chemicals may be significant. At high elevations the residence time of materials from engine exhausts may be very long—several years—so that in some areas the concentration may become significant. Possible effects are alterations in the rate of chemical reactions among the partly dissociated nitrogen, oxygen and water vapour constituents, by direct chemical interaction, or by absorption of radiation to provide thermal gradients. These effects in turn could lead to changes in general solar reflectivity and absorption, and ultimately to changes in climate. There is evidence that jet aircraft traffic has already caused a small increase in average high-altitude cirrus cloudiness in heavily travelled areas, and this must have an effect on the regional heat balance of the atmosphere.

Present data are insufficient to indicate the significance or magnitude of such effects and more research is required. However, until the processes and possible consequences are better known, caution is advisable in undertaking, on a regular or extensive basis, activities whose ultimate environmental consequences cannot at present be assessed.

Radioactive Materials

Any discharge of radioactive material into the atmosphere, streams or oceans represents a potential threat to the global environment. Any increase of radiation above the natural background can be expected to lead to an increase of generally adverse mutations during reproduction of life on earth. The amount of radioactive material released by nuclear power plants is exceedingly small, and under normal circumstances insignificant compared with fluctuations in natural radiation. A higher risk of discharge comes from non-energy uses of radioactive material, or from direct release, such as deliberate explosions. Nevertheless, as the number of nuclear power plants increases, so does the chance that a malfunction, accident in transport or storage or disposal of radioactive material, or other unforeseen

event might release dangerous amounts of radioactive substances. Some nuclear reactor systems used in other parts of the world are more susceptible to the accidental release of radioactive matter than the reactors used in Canada.

Waste Heat

The global effects of waste heat appear, on the basis of present information to be too slight to be important before the year 2000. Today, in areas of maximum industrial concentration, the man-induced heat discharge into the atmosphere may reach 10% of the solar radiation reaching the earth between Lat. 50° and 60°N. There is additional discharge directly into streams, groundwater and oceans. On a winter's day a city such as Montreal may lose to the atmosphere through its chimneys and exhaust gases considerably more heat than the total radiation it receives from the sun; but for Canada as a whole the total heat discharge from all energy sources is likely less than one-half of one per cent of the total solar energy received in any given period. Nevertheless, all major forms of energy used in Canada today discharge heat to the environment, and this heat must either accelerate environmental processes or raise the temperature. The effect is cumulative and in time could be important or even dominant among environmental concerns. Present evidence would suggest that the influence will be negligible for at least a generation, but more quantitative information is needed before it can be dismissed as of no significance.

Canada's Responsibility

Canada's international responsibility in regard to concerns about the present and long-term effects on the global environment of energy use is to:

> Take effective national action and work vigorously for international action to reduce or prevent the discharge of petroleum products and radioactive materials into the oceans and atmosphere;
>
> Participate in monitoring and research programs on the regional or global effects of combustion products and waste heat, with participation in developing an international action plan to control or mitigate harmful operations or effects when appropriate;
>
> Avoid, within her territories, action or technological developments that are of questionable net social value or for which there are alternatives, if such actions carry an unknown or indeterminable environmental risk.

Effects on the Environment of Canada

The regional or local environment of Canada is affected or threatened in a wide variety of ways by the multitude of activities connected with the production and use of energy in Canada. Some of the obvious ways are noted in the following paragraphs. The list is by no means exhaustive and serves mainly to show the range and diversity of impacts by energy activities on different facets of the Canadian environment, and to indicate certain areas where problems are troublesome.

Oil and Gas

Exploration and Production. Among the many potential problems associated with the exploration for oil and gas deposits in Canada and the exploitation of the deposits are:

Damage to the terrain, especially in boreal forest and permafrost areas, and to ecosystems, during the surface operations of exploration programs. The problems of disturbance of tundra soils with high ice content, the scarring of Arctic landscapes, the acceleration or erosion with consequent disturbance of drainage and destruction of fish spawning areas in parts of the Arctic are well known. Not so publicized are the effects in the boreal forest; in 1971 more forest was cut by the petroleum industry in the province of Alberta during the clearing of seismic lines than by the forest industries for lumbering, pulp and paper, and fuel. More subtle and widespread than the erosion of landscape or the clearing of strips of forest is the risk of damage to delicate northern ecosystems whose precarious linkages are vulnerable to dislocation by disturbance of sensitive species by noises, interference with breeding or migration, changes of watercourses, removal of gravel, etc., and by the continued harassment as increased accessibility consequent upon exploration programs brings more humans and their machines, for a variety of purposes, into previously undisturbed areas.

In this area of environmental issues one of the greatest difficulties is that of keeping a sense of proportion. Human activities in the Arctic or northern regions are bound to be at odds with Nature, just as they are in southern latitudes when we build a city or pave a road. But in our northern hinterland the damage can much more quickly get out of hand. It is wishful thinking to claim that economic development can proceed in the north without some damage to present ecosystems and terrain, although much can be done to keep the damage minimal. It is also unrealistic and self-defeating to assume that Nature will look after itself and recover if left alone after disturbance. In their own economic interests, and to show that they can manage at least part of their country intelligently for the long-term good, Canadians need urgently to find a way of putting a value on their undisturbed or naturally functioning hinterland, and of relating that value to the economic and social benefits of resource development. Then they may be able to apply their efforts realistically and not mainly emotionally or intuitively, toward preserving or protecting their land, and they may be able to assess and be aware of the present and future price they must pay or the net benefits they will receive as a result of its development.

Blow-outs or other accidents that result in the escape of significant amounts of oil or gas. In the offshore areas, and the North, especially, heavy pollution could result. Because of the distinctive character of the sediments and the presence of permafrost in the petroleum areas of northern Canada on land and in the Beaufort Sea, the problem of preventing blow-outs during exploration and development is very difficult. In some areas of encouraging potential for petroleum in Arctic Canada, ice is a significant component of the sedi-

mentary material down to depths of 1,000 metres or more; melting of this ice by hot oil or gas rising through a drill hole leads to difficult problems of hole management and control.

Escaped oil that finds its way into ice-covered waters will be most difficult to clean up, and can be expected to be more persistent, with a greater relative effect on the scarce aquatic or marine biota, than a spill of the same size in warmer waters. The areas of high potential for petroleum discovery offshore from both east and west coasts of Canada are also regions of very stormy waters, and this factor increases both the chance of an accident with subsequent oil leak or blow-out and the difficulty of controlling a leak if it did occur. The east coast area, from Baffin Bay to the Grand Banks, is also frequented by deep-draught icebergs, and there is as yet no known satisfactory technique for dealing effectively with icebergs and oil wells in the same place.

Air pollution from flaring gas or burning oil in waste pits. The practice of flaring unmarketable or unwanted gas and burning unusable oil, mostly impure condensate, is now very much reduced from a few years ago. Most such unmarketable material is now reinjected into the underground reservoir. But there are still cases, particularly in smaller fields, where reinjection is not economic, and from the producer's point of view, the easiest and safest practice, and one that prevents contamination of the ground or nearby streams, is to burn it. The effect on the environment will depend upon the composition (particularly the sulphur content) of the fuel, and on the location and design of the burning device or area. Flaring and burning practices can be controlled by suitable regulation, forcing other methods of disposal or use; but caution should be taken to avoid blanket prohibition, for in some instances flaring may be the least damaging to the environment of the practical methods available.

Disposal of brines which may be produced together with oil. Brine disposal has not been a major problem in most Canadian oil fields, but in some cases groundwater and surface water supplies have become contaminated. Proper management of brines requires a knowledge of the surface and subsurface hydrology of the region. For most brines, there appears to be no technological problem, should environmental or water-use problems demand it, in removing the unwanted salts and storing them or converting them to useful chemicals. Such a practice is not economic in Canada at present, but could be implemented when required to maintain water quality.

Disposal of solid wastes, including drilling muds and machinery. Because of the widely dispersed nature of exploration and development activities, "clean-up" operations may be as expensive as the main operation itself. This is particularly true in Arctic regions, where muds are not easily incorporated into the drainage system or the soil, and where land-use regulations and good environmental management require a fastidious removal of waste with care to prevent disturbance of the surface.

The problem of waste disposal on offshore operations has not been satisfactorily solved: monitoring or inspection and enforcement problems are formidable.

The federal government has responsibility to set guidelines that will prevent accidents and eliminate procedures that cause harm to the environment during the exploration for and production of oil and gas. Such guidelines should facilitate the inclusion of environmental considerations in the application of specific regulations, drawn up and enforced by provincial and federal governments respectively in their areas of jurisdiction, controlling the exploration activities themselves. In addition, the federal government has a responsibility to work toward the long-term improvement of standards and procedures, by undertaking, in cooperation with the provinces and industry:

A continuing review and up-grading, where appropriate, of the safety and environmental regulations applicable to exploration for petroleum deposits and production of oil and gas;

Continuing research into the physical and biological aspects, and the ecological relationships, of the known or potential petroleum areas of Canada and the surrounding oceans; and research into ways of lessening the undesired impact of exploration and production activities on the environment;

The development and implementation of a land-use program, particularly for undeveloped areas before development decisions are made or substantial investments committed;

Research, exchange of information, and international negotiation to develop and implement improved methods of management of the offshore marine environment during petroleum exploration and development.

The Problem of Tar Sands. The exploitation of the bituminous sands of Western Canada (and also of the Arctic Islands, if in the future that should be contemplated) will raise some difficult environmental problems which are a combination of those of petroleum production and open-pit mining. Two main methods of working the deposits are under test; (i) stripping and quarrying, by draglining or pit-mining machinery; and (ii) in-situ extraction of the bituminous matter. Both methods have advantages and limitations, and both have serious environmental problems. Among the factors affecting the environment are:

The enormous scale of the projected operations, which at full development will literally chew up or undermine and rearrange the landscape and local drainage of many hundreds of square miles of forested land;

The disposal of processed waste sand and overburden. If the stripping and quarrying method is used, an estimated 3 to 5 tons of material will have to be moved, processed and disposed of for each barrel of oil recovered.

In view of the low relief in much of the tar sands area, the prevalence of underground and interrupted drainage, the low stream gradients, the high proportion of silt and fines in the surface material, and the presence of discontinuous permafrost, the disposal of waste without causing serious environmental damage, locally and downstream, will require detailed knowledge and planning, and involve considerable expense. If the in situ recovery method is used, waste sand and overburden problems will be less, but the recovery of

petroleum is expected to be reduced by about fifty per cent, and water problems are greater;

The downstream effects, in the Athabasca-Peace-Mackenzie river system may be very extensive and serious, due to siltation and the dislocation of the normal seasonal hydrologic cycle. There is also a risk of pollution from escape of petroleum through accident or mismanagement. The downstream area includes the biologically richest part of northwestern Canada, and is the region where there are perhaps more native Canadians making a living directly from the land than anywhere else in the country. Many of the natural resources—moose, muskrat, and fish—are dependent on the river system, and alteration of its quality or behaviour could have severe and long-lasting consequences;

In addition to the potential effect of tar sand production on the river system, there are formidable environmental problems in securing an adequate supply of water for the petroleum recovery operation itself. A very large amount of water is needed for the recovery process, and as the operations move away from the banks of the main rivers this will be difficult to obtain. Unfortunately the chemical composition of the groundwater and of many of the smaller streams is such that, with the distinctive mineralogy of the tar sands, local waters in many places cannot be used directly in a continuous recovery process. With the recovery techniques used at present, process waters become enriched in sodium hydroxide, whose removal and disposal is difficult. Clarification of suspended matter in recycled circuits is a lengthy process, and a large-scale operation will require extensive settling ponds, whose management to retain efficiency during northern Alberta winter conditions may be difficult and lead to further problems of land use and water management. More environmental knowledge and development of techniques are required before the environmental aspects of the water supply problem for full-scale tar sands exploitation can be assessed.

Refining, transport, and storage of oil and gas. The refining of crude oil or the processing of natural gas can lead to pollution of water, soil, and air if not properly controlled, and could lead to concentrated damage in the case of fire or accident. Because of the high investment in refineries and processing plants, and their sophisticated technological nature, it is however entirely feasible to incorporate adequate environmental safeguards into the design of the plants, and to ensure that environmental control is maintained during its operation.

Some of the solid and liquid by-products of refining and processing pose a potential local environmental problem because of their corrosive or toxic nature, susceptibility to leaching, or cost of storage. Elemental sulphur from gas processing plants is an example. Many of these by-products are potentially useful and valuable, and the "environmental" problem can be expected to diminish as beneficial uses, and hence a market, are found, or to grow as over-supply causes the price to drop.

Crude oil is transported by tanker ship or by pipeline to the refinery; refined products by pipeline, rail, or highway. Natural gas in Canada, processed or un-

processed, is transported almost exclusively by pipeline; the amount of gas moved in liquefied form is negligible, but there have been considerations of the possibility of moving liquefied natural gas from the Arctic Islands by tanker at some time in the future.

Canada is vulnerable to environmental damage from tanker transport on all three coasts and in the St. Lawrence-Great Lakes waterway. Major environmental emergencies can result, and have resulted, from spillage of crude oil or residual oil from tankers through accidents, and has led to the establishment in Canada of a national contingency action plan to deal with such incidents, as well as action toward national legislation and international agreement to reduce their incidence. Such action must also control the non-spectacular spills; by and large the giant supertankers, despite their potential for serious damage to the environment are statistically among the safest means of transporting oil known and are less of a threat than the common small tankers. The small tankers comprising only 8% of the world tanker tonnage, account for about 50% of the current pollution from oil spills. It must not be overlooked that an amount of oil probably equal to that spilled in accidents enters the oceans and industrial waterways as a result of normal day-to-day operations of ships including their activities in harbour, deballasting and hold cleaning, etc. Almost all of this may be prevented by tough regulations and good management. More information on the behaviour of oil in Canadian waters, particularly in the Arctic and during winter, must be obtained before the consequences, particularly the long-term and cumulative effects, can be fully assessed. Research is also needed on the environmental effects of various clean-up procedures under Canadian conditions, for experience has shown that in some cases the clean-up operation has created more lasting damage than the spill. Such information is needed to improve both the shipping regulations and specifications and the oil spill contingency plans.

In non-permafrost areas, identified environmental damage from transportation of petroleum products by pipeline has been less per barrel of oil transported than from transport by ship or rail. The main damage has been through escape of oil through rupture or leakage, or environmental dislocation caused simply by the presence of the pipe, service road, and right-of-way. Escape of gas from a pipeline poses a potential fire hazard, and particurarly if the line or a pumping station should be involved in a forest fire, the consequences could be serious; but otherwise the effect on the environment is negligible. The most serious problem from escape of oil is contamination of streams, with a possibility of widespread effects on downstream aquatic life. The presence of a pipeline and right-of-way, which for reasons of economy is usually built in straight segments without regard for minor topography, may disrupt local drainage, increase soil erosion, have an effect on wildlife that is disproportionate to the land area actually disturbed, and be aesthetically displeasing. It should be noted, however, that the presence of a pipeline right-of-way has also been observed to result in a local increase in wildlife, by providing a strip of local grazing, second-growth cover, easier travel, etc.

In certain parts of northwestern Canada there is a moderate but definite risk that a pipeline could be broken by an earthquake. Pipeline systems in this area must be designed and equipped to minimize environmental damage in such an event.

In areas underlain by permafrost, the construction and operation of a pipeline, particularly a hot oil pipeline, poses special problems. In soils with a high ice con-

tent, heat from a buried line may cause the soil to become unstable, rupturing the pipe. The passage of the pipe from permafrost to non-permafrost areas, such as at river crossings, is especially difficult. The extensive amount of research and development in Canada, Alaska, and the Soviet Union, and the elaborate solutions that have been proposed, testify to the seriousness of these problems.

Problems connected with the storage of oil and gas are for the most part local and relatively small, concerned with safety in case of fire, containment in case of spillage, and disposal of material collected after a spill. A special problem exists in the north, where a stable foundation under a tank farm of warm oil is difficult to maintain on permafrost; proposed solutions have included continuously refrigerated foundations, yearly-cycle heat exchange units, and storage offshore below sea level.

In addition to its responsibility to set guidelines, regulations, and legislation for national and international commerce connected with the transport of petroleum and the safety of industrial operations, the federal government has an opportunity to help improve the ways in which the environment can be protected during refining, transport, and storage of oil and gas. Some appropriate ways are:

The continuous review of regulations and of their effectiveness in terms of both compliance by the industry and the resultant impact on the environment;

Cooperation and exchange of data with industry and with other countries, especially with research programs in Alaska and the Soviet Union, on the characteristics of the environment that are affected by oil spillage, and the effectiveness of various methods to mitigate potential or actual damage;

Background study in all related fields and careful assessment of acceptable "corridors" for petroleum transport, taking into account alternative or combined uses and the environmental, economic and social consequences of those alternatives;

The public release of information on the relative advantages and drawbacks, and known or estimated costs, of various methods of transport of different fuels.

Coal: Production and Transport

Environmental problems connected with the coal industry are:

Exploration of metallurgical grade coking coals in Western Canada, found in pitching seams of variable quality, requires total seam exposure by machine trenching along the outcrop, and can create serious erosion problems. Revegetation may be slow or nearly impossible, so that scarring of the landscape is long-lasting;

Strip mining disturbs extensive areas of landscape, and if soils have not been carefully removed before stripping and replaced during reclamation, the mineral surface will have very low fertility. The initial weathering of newly-exposed material after coal mining leads to acid water run-off and consequent stream pollution unless it is carefully impounded and controlled. Good management can essentially eliminate lasting environmental problems due to strip mining on the gently dipping coal seams on the prairies. However in the mountains it may be impractical or impossible to restore the topography

and vegetative productivity after mining, and it may be necessary to "dedicate" a portion of the valley to the mine, with permanent environmental change, as part of the price for winning the resource;

Underground mining, and to a lesser extent open-pit mining, may lead to instability of the strata after mining. This can be due to the physical removal of rock material, or to changes in underground drainage and consequently changes in the cohesion and strength of rock structures. Subsidence and landslides may result;

Contamination of the local drainage system may result from acid drainage from the mine itself or by leaching of tailings and waste dumps. This problem is troublesome mainly in mines in the Atlantic Provinces. In Western Canada the sulphur content of the coals is low and principally in an organic non-soluble form. Preventing acid contamination from reaching the regional drainage system is easy in principle, but in a working mine requires quite elaborate precautions that may be a serious burden to an operation whose profit is marginal;

Coal processing and cleaning plants produce leachable waste and contaminated process waters. In most cases the waste can be returned to the mine and the waters recycled, and the run-off purified through precipitation. If this cannot be done and strict environmental controls are enforced, the cost of treating the waste and water may well make the mine uneconomic;

Large amounts of mined and washed medium-to-low-grade "by-product coal" of useful thermal content but not of coking grade are accumulating in Western Canada as a consequence of the increased production of metallurgical coal. The impact on the environment is mainly aesthetic, although there are potential problems of wind-blown dust and instability of the coal piles. The problem can be expected to grow in magnitude as metallurgical coal production is expected to double to about 20 million tons per year, by 1980, and will no doubt have a strong influence on the urban environment, and on property values and social attitudes, in coal-mining communities. Eventually, of course, this by-product coal, with a carbon content of 50 per cent and more, may be a readily accessible resource, and the problem may disappear; but such an event is not foreseeable at present;

Transportation of coal in Canada is dominantly by rail. Associated environmental problems are minor, mainly those of land use, wind blown dust, and locomotive exhaust. Transportation by pipeline in slurry form, may be economically attractive in the near future; in this case disposal of the slurry waters, with dissolved chemicals and suspended particulate matter, may pose a problem;

Although the attractiveness of coal gasification from certain aspects makes it possible that test operations on a considerable scale may be established in the next decade or so, it does not appear likely that gasification of coal will play an important or large-scale role in the Canadian energy economy before the year 2000. Attendant environmental problems would be those connected

with large-scale mining, and the control and disposal of unwanted material, such as sulphur dioxide and siliceous particulate matter, from the processed gas.

It appears likely that a shortage of petroleum resources and rising prices may hasten the development of coal gasification in other countries before it will become profitable or advantageous in Canada. Some of these countries may encounter difficult environmental problems in large-scale gasification, because of land-use conflicts and the composition of their coals. Canada may thus have an opportunity to benefit from the experiences of others with regard to the environmental problems of coal gasification, provided we have the expertise to apply that knowledge to the Canadian situation. Canadian coals appear to be amenable to gasification with fewer problems, and thus less cost, than some foreign coals whose gasification is seriously being considered at present; and this may give the Canadian energy industry a future competitive advantage.

Combustion of Fuels

Pollutants and Their Behaviour. The most persuasive and easily identified undesired impact on the environment of Canada from energy activities is pollution of the air by products of combustion of fossil fuels. Of the many materials resulting from combustion which enter the atmosphere and change its natural character for brief or longer periods, some, like water vapour and carbon dioxide, are released in very large amounts, but their effect on immediate or short-term environmental processes in Canada appears to be slight or very subtle, at least in the southern areas, although the long-term effects could be important. The materials that have a known identified or potential effect on the environment in a manner that reduces its attractiveness or usefulness to man, and hence which are commonly called pollutants, can be divided into five main categories: hydrocarbons (HC); carbon monoxide (CO); the family of nitrogen oxides (NO_x); the family of sulphur oxides (SO_x); and particulate matter (Part), which comprises a wide and variable range of materials including metallic oxides and silicates, various metals including the heavy metals in salts and organic compounds, etc. Table 1 is based on surveys by the Environmental Protection Service of the Department of the Environment. It lists the major energy consuming sectors of the economy and the materials they contributed to the Canadian atmosphere from fuel combustion in 1971.

TABLE 1

AIR POLLUTION FROM FUEL COMBUSTION, 1971

(millions of tons per year)

	HC	CO	NO_x	SO_x	Part
Transport	2.4	14.4	0.8	0.2	0.06
Power generation	—	—	0.2	0.5	0.2
Other industry and commerce	0.04	0.03	0.2	0.9	0.13
Private and residential	0.02	0.07	0.05	0.2	0.04

Emissions from fuel combustion are responsible for about 65 per cent of the total emissions in these pollutant categories in Canada.

From Table 1 it may be seen that the transport sector of the economy is the most important cause of hydrocarbon, carbon monoxide, and nitrogen oxide pollution in Canada. Industry is the heaviest contributor of sulphur oxides from fuel combustion (and of course adds more from processes other than combustion of fossil fuels). Electric power generation plays a relatively minor role in air pollution in Canada today because only a part of Canada's electricity (22.2% in 1969) is generated by thermal means. Pollution from electric power generation could become more significant if, as expected, fossil-fueled plants increase proportionately in the next decade or so, and unless more effective pollution-prevention devices and procedures are incorporated into the new plants. However, it is likely that after about 1985 electricity from fossil-fueled plants will become increasingly costly compared to that generated by nuclear and hydroelectric stations, so that in the long-term future the role of electric power generation in causing potential or actual air pollution should again become minor.

The effects of the various pollutants from fuel combustion are complex and interrelated, and have received extensive study. The Environmental Protection Service, Department of the Environment, is the depository for information on this subject in Canada. Some simple observations related to considerations that must be borne in mind in connection with the national energy policy are:

Hydrocarbons, depending upon their type, can have various environmental impacts. Some hydrocarbons, in combination with nitrogen-oxides and particulates, can create photo-chemical smog, which can have, or be suspected to have, a significant effect on human health, on plant vigour, and on the durability of some materials, including plastics. Other hydrocarbons, dispersed widely and precipitated in streams and the oceans, enter the biological food chain with subtle but damaging effects. Some may be carcinogenic.

Carbon monoxide is a serious pollutant in areas of poor atmospheric circulation mainly because of its immediate and possibly progressive toxic characteristics. In the open atmosphere, it is short-lived as a compound and not likely to have significant effect on the natural environment.

Nitrogen oxides are of concern mainly in urban environments because of the toxic and corrosive qualities of some of them and their acidic derivatives. They are an essential component of a "good" smog, and also combine with aromatic compounds to enhance the disagreeable smells of a city or factory. There is evidence that in the presence of ammonia, nitrogen oxides may develop or activate carcinogenous compounds. In the natural environment they are converted to salts that are absorbed by plants on land and in water and eventually in dry areas concentrated in mineral soils. The overall effect of nitrogen oxides in the regional environment is probably one of aiding plant growth, and thus is probably positive in terms of net environmental quality, except in water bodies subject to eutrophication. However, the contribution from combustion processes is probably insignificant compared with that released from naturally decaying plant and animal matter and from fertilizers.

Sulphur oxides are toxic and corrosive. Sulphur dioxide in concentrations of 0.3 to 0.5 ppm or greater create demonstrable harm to vegetation, and have a corrosive effect on concrete, limestone, machinery and painted materials.

There is some evidence that prolonged exposure to much lower concentrations may have damaging effects on some forms of vegetation, such as conifers and lichens. Mammals, including man, appear to be able to tolerate somewhat higher concentrations, but experience discomfort; and physiological damage can result from exposure to the concentrations sometimes found in industrial communities.

The role of particulates cannot be generalized. Even components with very low solubility, such as SiO_2, may, because of their enormous relative surface area, form acid and hydroxyl compounds which themselves carry concentrations of other compounds, some of them potentially toxic. Particulates from some fuels, including leaded gasolines, carry substantial amounts of heavy metals. The presence of particulates may greatly alter atmospheric behaviour, by providing nuclei for condensation or crystallization, by acting as catalysts for chemical reaction, or by altering radiation absorption characteristics.

Abatement of Pollution from Fuel Combustion. For a given amount of energy produced by combustion of fossil fuels, air pollution can be abated in various ways:

The undesired emissions from internal combustion engines can be reduced considerably. Much publicity has been given to the establishment in the United States of standards which require that the emissions from automobiles manufactured in 1973 be reduced to 33% of those of typical pre-1968 cars, with a further important reduction demanded for 1976. While the U.S. 1973 standards are being essentially adopted by automobile manufacturers all over the world and hence will be in practice in Canada, there is some question as to the most appropriate longer term Canadian solution to the regulation of automotive emissions, and given Canadian conditions, uncertainty regarding the level of emissions over a long term at which the benefits to the Canadian environment would justify the associated costs and use of resources. It must be remembered that costs will run both ways: it will be expensive to pay for controls that may not benefit us, and it will be expensive to be different from our neighbours. Considerable research is necessary to establish the relationship between actual vehicle emissions using various technologies, driver habits and Canadian vehicle density, and its effect on the Canadian environment, and thus to determine the optimum course for Canada. Such studies are presently under way in the Air Pollution Control Directorate of the Department of the Environment, the Fuels Research Centre of the Department of Energy, Mines and Resources, and in Canadian industry. The Department of the Environment has the legal responsibility for enforcing the Clean Air Act as it applies to motor vehicles.

Reduction of air pollution can be made by switching to less-polluting types of fuel. This of course is only practical if supplies of "clean" fuel are adequate and the cost can be justified. The dramatic reduction in pollution from residential space heating in Eastern Canada consequent on the shift from coal-fired furnaces to oil and natural gas is an example. Several recent thermal electric power stations in Canada have been built to use either fuel oil or natural gas, depending on available supplies, environmental regulations, and

cost. The favoured fuel in all these arrangements is natural gas, which is in short supply on a continent-wide or worldwide basis.

This is an area where environmental considerations have a strong influence on prices (see Section II, main report), and where actions to meet present environmental concerns may make future environmental protection more difficult.

Such a circumstance demonstrates another problem that the national energy policy must face with regard to environmental considerations. Because its relative environmental cleanliness places a premium demand on natural gas as a fuel, its price is bound to rise in proportion to other fossil fuels. But the characteristics that make natural gas a favoured fuel from the environmental viewpoint also make it highly desired and nearly irreplaceable for other purposes. Sooner or later, and probably before long, it will be prudent to husband natural gas for those purposes for which only natural gas can be used, including petrochemical uses, rather than burning it lavishly in large power stations because it is the easiest way to keep a clean environment. Canada will then be faced with the decision of whether (i) to use natural gas as a fuel within Canada for its favoured environmental characteristics in the face of a high external demand and prices, or to (ii) control its use for any purpose because of its almost certain increased future value for non-fuel uses, or (iii) to consider to use it now as a negotiable income-making resource, which could help pay for the cost of protecting the environment when using "dirtier" fuels, currently or subsequently, and also help abate the initial cost of providing nuclear power. The net cost of nuclear power including the cost of environmental control of waste heat, and political developments with respect to foreign energy markets are likely to be key factors in this decision.

The emission of sulphur dioxide can be reduced through desulphurization of fuel oil from the present 3% contained sulphur to 1% or even 0.5%, and by further removal of sulphur from stack gases. However, there is at present no practical method of removing 100% of the sulphur dioxide from stack gases on an industrial scale, and this problem brings up the question of the effectiveness of tall chimneys as a method of environmental protection.

There is controversy over the practice of dispersing effluent through higher and higher chimneys. Clearly higher chimneys provide an opportunity for the effluent to be spread through a larger air mass, and other things being equal, will result in lower pollutant concentrations. But the total pollutant load is not reduced. Clearly also the atmosphere is a very effective cleanser and neutralizer of pollutants, up to a certain level of concentration; but we have really very little idea of its capacity in this regard in most regions, and measurement of the behaviour of pollutants in a plume and the area of precipitation is exceedingly difficult and expensive. The "trial and error" method of establishing acceptable levels of pollution concentrations will not work because of the heavy investment in plant design and stack construction, and because by the time that deleterious results on the environment become apparent, a progressive sequence of damage has already gone too far. The atmosphere

is clearly not a simple dilutent; it also has the ability to concentrate airborne constituents and to carry them long distances without losing their distinctive character. The black snows of Norway and the acid rains of Sweden, with components traceable to specific industrial regions of Britain and Germany, are examples.

For these reasons, dispersal of effluent through high chimneys is not an easy solution to the problem of sulphur dioxide pollution. It can only be an interim solution until the atmospheric and full environmental behaviour, and the range of their vicissitudes, is known. It is a self-limiting solution, for it can only be effective if it is certain that other pollution loads will not be added to the atmosphere in the same region. Provided, however, the pollution load is kept well within even the most pessimistic estimate of the capacity of the local and regional airshed to deal with it, and that the emission itself does not have a direct adverse or displeasing effect on the immediate area, controlled dispersion to the atmosphere may be an efficient and environmentally satisfactory method of pollution control. It may be well suited to an isolated mine or a power plant in the hinterland. It may also represent the "best practicable technology" for domestic heating units and for the disposal of the last bit of sulphur dioxide from the "scrubbed" gases from an urban factory.

Much particulate matter can be removed from emission gases by cyclones and electrostatic precipitators. However, it becomes very expensive, and impractical for small installations, to reduce particulate emission to a very low level; the process must be designed and adjusted for each fuel batch and each installation. Some particulate control can be effected directly, if desired, by fuel quality control; e.g. elimination of added lead from gasoline will reduce particulate lead from the exhaust. More research is needed on the action and environmental consequences of particulate emissions from typical Canadian fuels in typical Canadian uses, and on the technology of their control.

The national energy policy should encourage the work of the Fuels Research Centre and the Environmental Protection Service in finding practical, economical and effective ways of further reducing the undesired environmental impact of using Canada's resources of fossil fuels, and should enable the nation to make use of the results of such research.

Nuclear Power

Various studies in Canada and elsewhere have led to the conclusion that electric power produced from nuclear energy will have a lower overall environmental impact than that from any other contemporary power system. That this is predicted to be so is due at least in part to the very close regulation of nuclear energy systems at all stages from design and choice of location to construction and operation, in this and other countries. Regard for the potential effects on the environment is an essential part of the purpose of this strict regulation. The Atomic Energy Control regulations in Canada, and similar regulations in several other countries, require that the safety and environmental impacts of a nuclear

power plant or other facilities handling nuclear or fissionable material be evaluated by an independent control agency prior to approval for construction of a plant. This process has proven to be effective in ensuring safety and minimum environmental impact, and could serve as a model for controlling the safety and environmental impact of other industries.

All parts of the nuclear fuel cycle must be considered when assessing the environmental effect of nuclear energy. They can be grouped into two main areas: the mining, transport, and refining of radioactive materials; and the generation of power by nuclear reaction, with disposal of the resulting wastes.

Mining, Transport, and Refining of Radioactive Materials. Mining of uranium produces environmental problems similar to any other type of mining, with two additional problems. The conventional problems are those of land disturbance, waste disposal, and water supply contamination. However, in Canada these problems are relatively straightforward and with proper planning and management can result in minimum effect on the environment because:

Uranium mines are comparatively small in extent, compared with mines of the lighter metals or coal.

Uranium mines in Canada are all in areas of hard crystalline rock, and of a mineralogy such that the waste rock newly exposed does not weather with a surface toxic to plants. Most mines are in areas that are relatively infertile to begin with, and the reclaimed land has in places proved to be a better site for natural vegetation than the original land.

The special environmental problems of uranium mines in Canada are:

The possibility of danger to workers in underground mines and their associated mills due to radon emissions. This danger is one of the industrial or work environment, and it is unlikely that the situation will ever be encounterd where there is damage to the natural environment outside the mine itself. The danger can be minimized by adequate ventilation within the mine and by rotation and scheduling the workers to control the time spent in critical areas. Modern statistics of health injury to miners of radioactive ores show that with present understanding and management, and the awareness of the miners and mill workers themselves, risks from accumulated radiation are negligible in uranium mines today;

The possibility that radioactive material from mine drainage or leaching of tailings may enter the nearby streams. This hazard can be controlled by adequate monitoring, impoundment of water for critical periods, control of discharge, and by suitable design of tailings areas to prevent uncontrolled leaching. It should be noted that the surface and ground waters in areas of uranium deposits generally have a locally high natural "background" of radioactivity due to natural leaching of radioactive materials.

The transportation of uranium ore and concentrates in Canada is usually by rail or road and does not present any particular environmental problems due to the composition or radioactivity of the ore.

The conversion of ore concentrate into reactor grade uranium, and the manufacture of reactor fuel for the CANDU reactors have no potential environmental impact. Some systems used in other parts of the world require enriched uranium and hence uranium hexafluoride (UF_6) as a feed material to the enrichment plant. A plant to produce UF_6 is in operation in Canada. Special precautions are taken to ensure that the chemically active fluorine and fluoride are carefully contained.

Power Generation by Nuclear Reaction. There are two general aspects to the environmental aspects of power generation from nuclear energy:

The release of radiation or radioactive substances from the various activities involved in producing power and disposing wastes;

The potential for accidents which could lead to unplanned release of an important amount of radioactive material.

The discharge of radiation or radioactive material from a CANDU type reactor during fueling, operation or maintenance, is extremely small, and over several years' experience has been found to be, in the immediate vicinity of the plant, no more than 5% of the background of radiation received from cosmic and natural terrestrial sources. There is discharged approximately 40 to 50 per cent more waste heat per kilowatt hour of electricity produced than from thermal power stations, but this heat is discharged through cooling waters quite devoid of radioactivity. The total amount of radioactive waste generated by a CANDU plant is small in physical volume and almost all of the radioactivity is concentrated in the spent fuel. This fuel can be stored very safely, initially in water-filled bays and after some months in air cooled vaults.

Reprocessing of spent fuel is not done in Canada at present since it gives no economic advantage with the current CANDU reactors; however it is likely to be carried out in the future to recover the valuable plutonium in the spent rods, and such an operation could potentially lead to release of liquids containing radioactive material. The technique for reprocessing spent fuel and recovery of plutonium has been developed in the United Kingdom and the U.S.A. and it has been shown possible to keep the release of radioactive material to an insignificant level. The potentially hazardous liquid waste from such reprocessing has been stored without mishap in the U.K. and U.S. for approximately three decades. Techniques exist for converting this waste to an insoluble glass which could be placed in suitable rocks for permanent disposal, if necessary. None of these problems is immediate for Canada.

The question of the safety of nuclear facilities has been a major factor since the first development of nuclear energy. Nuclear power plants are designed with safety systems to cope with all foreseeable malfunctions of the nuclear power plant. In addition they are housed in structures which are designed to contain any radioactive material which might be released in the event of an accident, even if the safety devices do not operate as intended. This multi-tiered approach to safety when coupled with the practice (and regulatory process) of thoroughly analysing designs for potential accidents ensures that the likelihood of a radioactive spill from the plant due to accidents is extremely small.

There remains the questions of whether a nuclear power plant of the CANDU type could pose a major environmental hazard in the case of deliberate sabotage or malfunction by a knowledgeable person, or in case the entire structure is disrupted by a bomb in case of war. That it would be possible for a large amount of radioactive material to be exposed to the environment in case of a carefully planned wrecking of a nuclear plant is true; but it would require a major co-ordinated operation. Simple demolition of a plant by a bomb would likely result only in a local "hot spot" and release of only a minor amount of radioactive material. In any case, there is no physical possibility that the material in a nuclear power plant can be accidentally or deliberately made into the critical collection of materials necessary to generate a nuclear explosion.

An associated activity of nuclear power generation using the CANDU process is the production of heavy water. The process currently in use employs hydrogen sulphide-water exchange. Large quantities of toxic H_2S are used, and these could present a potential environmental hazard. The risk is similar to that in many other chemical operations, and must be kept small by appropriate design of the system and management of the operation.

The licensing system in existence under the Atomic Energy Control Board provides the means necessary to ensure that the safety and environmental impact of nuclear power plants and other nuclear facilities are fully controlled. Experience to date in Canada indicates that except for the discharge of heat, the introduction of some biocides added to control the organic content of circulating plant waters, and the land-use problems connected with the need to site plants where cooling waters are available, but also close to centres of power consumption if possible, the environmental impact of generating electricity by nuclear reaction is essentially negligible.

Hydraulic Power

The energy from stream currents and water under hydrostatic pressure has been an important source of community and industrial power since the beginning of the technological age. A large number of Canadian communities were founded because a rapids or dam site offered the opportunity for a water-powered mill or factory. Early in the twentieth century, direct water power gave way to hydro-electric power, and communities distant from streams and dam sites were able to make indirect use of hydraulic energy. Canada became more and more dependent on water power, and by 1939, at the beginning of World War II, 92 per cent of the electric power generated came from hydroelectric plants. Since then the total installed capacity of hydroelectric power has increased five-fold, but large thermal plants have also been installed to help meet the growing demand for electricity, so that although the amount of electricity provided by hydraulic power continues to increase, its proportional contribution to the national energy supply is falling. Of the total generation of 190,093,000,000 kWh of electricity in Canada in 1969, 77.8 per cent was produced from water power. Prince Edward Island, Nova Scotia, and Alberta are the only provinces that do not depend on water power for the bulk of their electricity. To many Canadians, the word "hydro" means not water, but electricity.

The synonymity of electric power with dams and streams in Canada leads to an assumption that electricity comes directly from nature, and a popular feeling that man's use of a river to make power is an intelligent use of the environment, akin to ploughing the land and planting a crop. Thermal power generation, on the other hand, is widely regarded as somehow artificial, justified only when water power is not available. These feelings have a bearing on the national attitude to the environmental effects of hydroelectric power development.

The environmental effects of a major water storage dam are manifold, far-reaching, complex and often difficult to predict. The effects will be felt both in the storage area and adjacent valleys, and downstream throughout the whole stream system. Many of the effects are irreversible as long as the dam remains in place. It should be noted that the effects may have positive as well as negative aspects on those parts of the ecosystem that man believes to be important; the dam may increase biological productivity and the overall usefulness to man and to certain members of the wildlife of the area.

In one respect, a dam and storage reservoir differ from most other energy activities as regards the type of impact on the environment. Hydroelectric development does not introduce new or alien substances, states of matter, or heat into the environment; it merely creates, quickly, a physiographic condition that, except on the Prairies, is natural to the region. A hydroelectric dam simply provides, suddenly, a new lake and a waterfall in a land where there are in most cases already lakes and waterfalls being created and destroyed slowly through geological processes. The ecosystem of any area is continually adjusting to the evolving physiographic and hydrological characteristics of the area. The environmental and ecological effects of a hydroelectric power development are those consequent on the suddenness of the physiographic change, not on the introduction of something alien. The change may be nonetheless drastic, and the ecosystem may be violently disrupted; there has not been a lake on the Prairies equivalent to Lake Diefenbaker since the waning of the Pleistocene ice sheets, but the essential components of the lake are similar to those of nearby ponds and ox-bows.

The construction of a major dam modifies the local physical environment and replaces it with two different environments,—downstream and in the headpond. In many sites, although the change is most obvious to humans in the headpond area, it appears that the most important environmental and biological effects occur downstream. In most cases, the headpond or storage reservoir is already to some degree a lake or quiet water area, with both aquatic and terrestrial ecosystems appropriate to the local environment; creation of a dam dislocates the shoreline, which is a sensitive and critical area for both land and water life, but although resident populations may be damaged or extinguished, the Canadian shoreline biota is accustomed to this from natural events, and a new shoreline balance becomes sooner or later established. If the headpond floods large areas of forested land, the drowned organic matter may reduce the oxygen content and release organic acids, lowering its productivity for a time; thus it is good management to be as fastidious as possible in clearing the land before flooding. But often in a surprisingly short time—a decade or so if the new water level is held reasonably stable—headponds of hydroelectric plants in most parts of Canada become chemically and biologically very similar to the natural lakes of the region,

unless there are complications introduced by their accessibility and consequent human use. Like any other lake, a headpond will become a depository for silt, will modify the local climate by increased water evaporation and heat capacity, and will affect the accumulation and break-up of ice in the local drainage systems. If the power generation operation is one in which the reservoir drawdown is severe and erratic, a stable shoreline cannot develop, and biological productivity may be quite different and much less than if the water level is stable.

This is also a situation occasionally found in natural lakes in Canada and such lakes are also generally poorly productive, environmentally unattractive, and to human ideas, a handicap to the ecosystem.

Perhaps the most severe environmental problem to be faced with regard to the water storage areas of major hydroelectric schemes is that of providing for sufficient shorelines with reasonably stable water levels so that typical wetland habitat, vital to the terrestrial and aquatic ecosystems, can be maintained. In areas where considerable water-level variation is planned from an operational or engineering viewpoint, the creation of perched lagoons or basins that can maintain wetland habitats should be a minimum environmental requirement.

The increased local crustal loading due to filling of a storage reservoir could conceivably trigger local seismic movements, and there is evidence that this has happened in some places. In areas of unstable surficial materials, or underlain by permafrost, both the dam itself and the water in the storage reservoir can be responsible for sudden or slow and continuous soil movements.

Downstream from the dam, the most important effects are due to:

> The controlled outflow, which is likely to reduce the strong seasonal fluctuations in flow and in water temperature to which the ecosystem and the valley physiography are adjusted. In particular the spring freshets are likely to be diminished, reducing the ability of the stream to break its ice cover by mechanical means; this can seriously affect the date of germination and reproduction of life both in the river and throughout the valley. If the fluctuation in flow is still significant when the river reaches the sea, the conditions in its estuary or delta may be drastically changed, and the local sea ice regime and marine food supply may be altered;
>
> The reduction in the suspended and base load of the stream. The processes of aggradation and erosion will be dislocated; the available food in the river may be reduced; and the downstream valley will subtly change character. To this change in the stream will be added the accumulation of coarse debris from the dam and powerhouse construction itself, and the effects of increasing or different human use of the valley.

A hydroelectric plant that uses part of an existing waterfall, or which taps a high-level lake without significantly altering its level, has very slight effect on the environment beyond the disturbance due to the construction itself and the access roads, the creation of local stream diversion, some modification of the pattern of downstream flow, and possibly hindrance or prevention of migration of fish and aquatic invertebrates.

A further environmental problem of hydroelectric installations arises from the fact that, unlike that from thermal power plants, electricity from a hydroelectric plant can be generated or turned off quickly—almost literally, by the turn of a tap. Hydroelectric power is thus ideally suited, from the engineer's point of view, to peak load operation. To an increasing degree, it can be expected that nuclear or thermal power will be used in Canada to meet the base load demand for electricity, and hydroelectric power turned off and on as peak loads vary. This fluctuation in generation and thus in water discharge from the tailrace, can have very awkward environmental consequences downstream, and to a less extent upstream as reservoir levels vary. A case could be made for prohibition of peak load fluctuations during periods of fish spawning in certain areas.

Some of the environmental effects of a dam and headpond can be controlled or overcome by dam design and operational techniques. Fish ladders, silt control equipment, flood bypass channels, shoreline lagoons, etc. may mitigate or control some of the obvious environmental effects. But little can be done to eliminate the more profound effects due to the presence of the installation itself. These must be weighed against the benefits.

The main environmental effects of hydroelectric projects are thus changes of land use. Valley floor flooded by a headpond is likely to be biologically the most productive part of the regions, and both humans and terrestrial wildlife will be displaced to less fertile areas. Areas of potential mineral deposits, or of historical or archaeological significance, will be lost or destroyed.

The newly created lake may have a local tempering effect on the climate, and may lead to warmer surface waters in summer; and it may become more productive in terms of fish, waterfowl, and recreational potential. Or if a stable shoreline cannot develop, it may become more barren. But the area downstream, under Canadian conditions, is likely to experience a subtly longer winter and may on the whole become less productive. Careful assessment must be made of the balance between all these factors, and the benefits to be derived from the power obtained.

It is apparent that each proposed hydroelectric project must be treated as a special case to evaluate its environmental and social effects and decide on whether the potential benefits outweigh the disadvantages or costs. Extensive prior study of the physiographic and hydrological effects and the possible disturbance to the ecosystem, involving the best knowledge from all relevant disciplines and consultation between all interested parties is required. A high degree of coordinated planning is essential to ensure that environmental effects are anticipated, and kept within acceptable limits. There is an urgent need for thorough study of the "before" and "after" situation in established installations, and public discussion of these, to serve as guidelines in assessing proposed projects.

Production of Electricity from Other Sources

Many schemes have been proposed, and spasmodic serious research has been undertaken into the possibility of producing power—in the form of electricity or transportable concentrated heat—from sources other than those presently used. The most attractive alternatives are wind, which is a by-product of solar energy, direct use of solar energy, tidal energy, and geothermal energy.

Current research in these areas, and the outlook for their possible application in Canada, are summarized in Part 1 of this Appendix. The following comments touch on some obvious environmental implications.

Wind. Wind was used for several centuries to move trade goods around the world, very crudely but with a cost/ton-mile efficiency that has not since been equalled, and was until recently in widespread use as a source of low-intensity local power. Of all the sources of energy obviously available to man today, the utilization of wind gives promise of being harnessed with the least harmful effects on the environment; it adds no locally new material to the atmosphere or streams, and together with geothermal energy is one of the very few forms of energy that appear possible of utilization without adding to the world heat load. Assuming that the conceptual and technical problems of efficient extraction of energy from wind, and the more difficult problem of storage of the energy to provide a steady power supply, can be solved, the environmental problems associated with utilization of wind power on a large scale appear to be mainly those of land use. Large installations will be required at exposed sites, which would likely have to be dedicated exclusively to that purpose; and it may be necessary to rearrange the topography on a massive scale to control atmospheric movements so as to concentrate and extract maximum energy. The very difficult problem of massive energy storage may or may not raise serious environmental problems. At the present time, pumped water reservoir storage appears to be the most efficient means available; if this is the method used, it would require large paired reservoirs, at high and low levels, near each site, with all their environmental consequences.

Solar Energy. Although the energy received directly from the sun is potentially the most abundant form of energy available to man, no methods of concentrating it into sustained power suitable for industrial use have yet been devised. Any such method based on collecting solar radiation at the earth's surface would appear to be of most interest to low-latitude countries with dominantly clear skies, and to hold comparatively low promise for Canada, which has a low incidence of radiation particularly in winter when the demand for energy is highest, and a moderately high average cloud factor in most places where energy is required. Thus it appears most unlikely that installations to collect solar radiation over large areas, with their consequent land-use problems, would be built in Canada until after the techniques have been proven and refined in warm, sunnier areas.

There are two aspects of the Canadian environment, however, that have given rise to some speculation as to whether in the future they may be turned to advantage in the utilization of solar energy. One is the enormous transfer of latent heat that takes place twice annually over much of Canada, without significant change of temperature, as the ice and snow cover melts and then the waters freeze. It has been postulated that it may be possible to utilize this process to accumulate and release heat under control. The physical basis and the technology of such a scheme is speculative in the extreme, and the potential environmental consequences unknown.

Another speculative but conceivable use of the distinctive Canadian environment in the utilization of solar energy is that if solar energy were to be collected in space, outside the earth's atmosphere, and re-radiated to earth, as has been

proposed in a number of schemes, it may be most efficient to direct that energy to earth in the region of the polar geomagnetic cap, much of which lies over Canada.

All schemes dependent on collecting or managing solar energy appear to have very great and special requirements in terms of land use. None of them would appear to have any practical consequences for Canada for many decades.

Tidal Energy. Canada has several sites on both coasts where, if harnessing tides to produce electric power were to become economically attractive, it would conceivably be possible to build tidal power plants. To be effective, such plants must interfere with the cyclic flow of water in the inter-tidal area, and thus they could have a strong effect on the physiographic processes and biological productivity of the immediate area. Each installation should be carefully studied before plans are approved, to determine the environmental and ecological effects of a tidal dam and power station, but it appears that in most cases the degree of interference with natural processes will be insignificant on an areal basis and the environmental impact will be local. Of much greater potential impact, perhaps, is the energy storage scheme used. If it is to be a pumped water reservoir separate from the tidal basin, conflicts of land use could be serious.

Geothermal Energy. Geothermal energy appears to be available to Canadians only in restricted parts of British Columbia, Yukon, parts of southwestern Alberta and, conceivably but farther in the future, off the east coast and in the Arctic Islands. If any of these sources can be developed as a source of power, the environmental impact can be expected to be small. The main problem will come from corrosive discharge waters and condensates. Experience in using geothermal power in other parts of the world, however, shows that the local drainage system and ecosystem is usually adjusted, naturally, to the distinctive chemical environment. Thus while the diversion of subterranean emanations through a power plant may cause severe problems for human works and some risk to workers, the environment outside the immediate plant area is little affected.

Transmission and Storage of Electricity

The transmission of electricity is traditionally by means of multiple wires, supported on towers, feeding transformer stations that in turn feed smaller distribution lines. The impact on the natural environment is primarily aesthetic, due to the insensitive way in which cleared rights-of-way, structurally functional support towers, and wires march across the country with little regard to local topography, vegetation, or other land use. A secondary impact is the effect that the rights-of-way and access roads may have on drainage and wildlife. A third and probably insignificant impact is the effect of the local induction envelope and the voltage potential across insulators. There is also a risk, nearly negligible in importance, that collapse of a tower or other accident could cause a forest fire or electrocution.

The demand for ever longer-distance transmission lines and the desire to reduce power losses can be expected to lead to higher voltages—possibly above 1,000,000 volts—and to the introduction of direct-current lines. The cost of these

will put even more emphasis on shortest-route rights-of-way, with a consequent increase of conflicts of land use.

The environmental problems of electricity transmission are for the most part a simple case of cost and engineering efficiency on the one hand and social, environmental and aesthetic values of the other. There is considerable room for flexibility. The line can be run almost anywhere, even underground (though this is of doubtful net benefit to the environment in many areas); the support structures can be as decorative as one may wish—but only at an increased capital and operating cost and thus an increased cost of the energy delivered.

The need for coordinated planning and an integrated program of land use, for undeveloped as well as developed areas, is evident. A method of balancing aesthetic and environmental needs against energy cost, without having to set a discounted dollar value on the future worth of unspoiled scenery, is urgently needed. There is much room for discussion and cooperation in planning of routes, in multiple use of right-of-way with transport and other utilities, and in exchange of information on the implications of the various alternatives. But in the final analysis, if Canadians want to turn their lights on, for the next few decades at least they will have to string wires from the generator to the light socket.

Man at present does not know how to store electricity in large amounts except temporarily as a charge on the plates of a condenser (or in a thundercloud). Generated electric energy is stored in Canada in significant quantities in only two ways: chemically, as in batteries; and in the form of potential kinetic energy, as in a pumped storage facility for hydroelectric regeneration. Chemical storage in batteries leads to no significant environmental problems, except a minor one of waste disposal. Pumped storage reservoirs and regeneration facilities are a special case of hydroelectric plants.

Waste Heat

All major transformations and uses of energy in Canada today generate non-useful heat. For most purposs for which we use energy—transportation, lighting, industrial processes, household utilities—more energy is lost or discharged to the surroundings in the form of waste heat than is utilized directly to accomplish the purposes for which the energy is applied. Some estimates made in the United States, incorporating admittedly broad assumptions, indicate that only about 20 per cent of the available energy in the fuel consumed or hydroelectric power generated performs useful work; the remainder escapes or is deliberately discharged as waste heat. There is no reason to suspect that the "thermal efficiency" of Canada is much different.

Although a great deal of waste heat is dissipated to the atmosphere, through chimneys, exhaust pipes, automobile radiators, etc., the most concentrated amounts, and those with greatest potential for environmental change or for possible beneficial use, are discharged into cooling waters from thermal and nuclear power stations and major industries such as refineries and paper plants.

Table 2 indicates the order of magnitude of the known heat discharge into Canadian waters from these sources for 1970, and the projected discharge in the year 2000 if present energy and industrial trends continue.

TABLE 2

HEAT DISCHARGE INTO CANADIAN WATERS FROM POWER GENERATION AND INDUSTRIAL PROCESSES

	Great Lakes		Other Fresh Water		Tidal Water		Total	
Year	1970	2000 (Est)	1970	2000 (Est)	1970	2000 (Est)	1970	2000 (Est)
Heat rejection Btu/hr x 10^{10}	3.165	60	1.65	38.6	1.21	38.1	6.025	136.7
Water loss by evaporation to dispose of added heat US gal/day x 10^{6}	69	1308	36	846	28	838	133	2292

It is clear that if the current trend were to continue to the year 2000, the heat discharged into Canadian waters, and the increased evaporation resulting, will have an important, and not as at present a minor local, impact on the environment. It should be noted that these figures do not take into account the addition of heat from United States sources into the Great Lakes system, which will further modify the Canadian environment; nor do they attempt to quantify the change of temperature of the water masses.

The addition of concentrated heat to a water system places a severe strain on the ecosystem. It is not the total amount of heat added that is most important, but the change of temperature and the temperature gradient. Many species in the aquatic food chain are very sensitive to changes in temperature, and even though they may be physiologically tolerant of the change, their behaviour alters. Biochemical processes are speeded by higher temperatures, and species may appear to thrive and grow faster in slightly warmer waters. The problem with viewing this as an environmental benefit is that in most cases it is the lower forms of life, the parasites and bacilli, that adapt and respond more readily than the higher and more organized species, and the ecosystem is disrupted. Thus while fish congregate readily at the warm outlet from a power station because of increased food growth there, like children at a free candy store, they soon get sick.

Because coldness is a familiar source of discomfort for Canadians, and a basic reason for the low average annual biological productivity of our country, there is apt to be wishful imagining that if our waters are so cold, it would be an environmental benefit to warm them up. In fact, the addition of substantial amounts of heat into cold waters is, relatively speaking, more of an environmental shock than it would be in warmer waters, where the temperature contrast would not be so high. Thus, schemes of using waste heat to accelerate useful biological activities in aquaculture, etc., must be carefully assessed, with a good understanding of the whole biological and environmental mechanisms concerned, or they may become self-defeating. In general, schemes to use waste heat to enhance biological productivity appear to have a hope of success only in artificially managed areas of restricted circulation, and not in open natural drainage systems.

A further problem arising from waste heat from power plants is that it has often been found necessary to add biocides to cooling ponds, cooling towers, and discharge pipes, to prevent excessive algae and gastropod, etc., growth which could interfere with the efficiency and operation of the plant. When these waters are discharged, the biocides go too; the heat will soon be dissipated, but the poisons may still have potency.

Waste heat in waters can of course be used beneficially for local purposes such as keeping locks open, melting ice at turbine intakes, etc., without major ill effects to the environment. But uses of this kind identified to date in Canada are very minor.

Much can be done to reduce the net discharge of waste heat into Canadian waters. Methods of re-cycling cooled waters, increased efficiency in the plant itself, more effective heat exchange systems, etc., can be applied, often at little cost if the desirability of avoiding heat discharge is realized. There is a fruitful field for research into ways of using the large amounts of low-temperature heat discharged, and so converting some of the "waste" heat into useful heat without damage to the environment.

Chapter 6

THE COST OF ENVIRONMENTAL PROTECTION IN ENERGY PRODUCTION AND USE

The foregoing comments lead to the conclusion that with proper management and control and application of known or reasonably foreseeable technology, it is possible to mitigate or eliminate all of the major undesired influences on the Canadian environment arising from the production and use of the kinds and amounts of energy expected to be required in Canada until the year 2000. Thus it is technically feasible to provide adequate energy for predicted Canadian needs and still maintain environmental quality as good as or better than that of today. It is clear, however, that such control and quality maintenance cannot be achieved without cost, and without a loss in the short-term efficiency with which energy is used.

Canada has adopted the principle that those who damage the environment or who produce or use polluting products should bear the cost of environmental restoration or preservation; it should not be a direct charge on the public purse. Thus the cost of meeting appropriate environmental standards should be included in the price of energy and non-energy products and services. It is important that these costs include the costs of environmental assessment and the costs of design to maintain environmental quality, as well as the direct operational and management costs of environmental protection.

No nation has experience in applying the vigorous controls and coordinated attention to environmental effects that will be necessary, involving everyone from resource developer to individual consumer, in the next few decades if environmental quality is to be preserved while energy consumption grows. Much of the technology is experimental or prototype, and its cost in mass application is unknown. The largest single expenses are expected to be those connected with industrial plant re-design or conversion, and the overall net costs will depend upon the method of financing major changes that cannot be expected to lead to greater profits. We do not know the stockholders' reaction to this situation. Nor do we know the degree of social acceptance of environmental measures and the price that the individual Canadian will be willing to pay for a future clean environment when he finds that his costs are increasing and his heretofore freedom of choice and action is limited by environmental considerations. Consequently estimates of the costs of environmental protection in energy production and use are largely speculative.

The most important short-term and middle-term costs are associated with the development and operation of cleaner automobiles and their appropriate fuels, cleaner electric power generation in populated areas, reduction of air and water pollution from industrial use of energy, and environmentally better ways of finding and producing oil, gas and coal. The heaviest expenses will be incurred, in the first instance by the automobile and petroleum refining industries, by utilities in desulphurizing fuel oil and imported coal or switching to more expensive cleaner fuels, and by producers of energy materials through environmental control in resource exploration, at the wellhead or mine.

On a longer-term basis the costs of environmental quality stabilization due at least in part to the use of energy may become considerable in connection with:

Reorganization of patterns of land use and mechanisms of land-use management;

Improvement of worldwide marine and land fuel delivery and distribution systems;

The extraction, desulphurizing, and processing of coal, including coal-derived secondary fuels;

Control and beneficial utilization of low-temperature waste heat;

Control of suspended particulate matter, radioactive materials and persistent harmful compounds.

Estimates of the dollar cost of achieving and maintaining environmental quality while producing and using energy in the anticipated amounts during the next decades must necessarily be based on many assumptions and guesses, and they must continually be modified because of changes of technology and prices. A recent analysis of the "order of magnitude" costs of driving a car in Canada equipped to meet the United States "1976" emission standards shows that the yearly cost to a typical Canadian driver would increase $200 to $300 per vehicle, equivalent to an increased cost per mile of about 7 per cent (Chapter 8). This estimate assumes a full-size Detroit-type vehicle with modified "conventional" engine with dual catalysts. Other types of vehicles and other designs of engine—carbureted stratified-charge, Wankel, and diesel—would give different estimated costs, because of different estimated initial costs, performance, and fuel consumption. But none are expected to be cheaper to buy or operate than the vehicles used today, and it does not appear that they will be prohibitively more expensive by today's standards. Canadian automobile regulations may not be identical with those of the U.S., western Europe or Japan, but it is not likely that compliance under Canadian conditions will be less expensive.

The additional costs that new electricity generation facilities and transmission systems will have to incur in this decade to meet environmental considerations are difficult to estimate, because such considerations influence the choice of the type of plant and its location, as well as its design and operation. It appears, however, that an increment of one mill per kWh of electricity produced over twenty years would adequately cover a thorough pre-construction environmental survey and assessment, environmental design costs, capital and operating costs of abatement

of air pollution, some control of waste heat effects, and environmental rehabilitation in connection with hydroelectric projects, given the mixture of fossil fuel, nuclear and hydro utilities likely to be built in Canada in the next decade. For those plants using desulphurized heavy fuel oil, there would be an estimated additional operating cost of about $0.50 per barrel, or 0.7 mill per kWh electricity produced. It is assumed that coal-fired power stations, except in the Maritimes, will be able to continue to use low-sulphur or imported desulphurized coals, so that the national cost of coal desulphurization will remain small.

The estimated cost of oil and gas from the Arctic includes a high allowance for the expenses of protecting the Arctic environment. As all Canadian Arctic fuel resource development and transportation will be undertaken from the beginning under strict environmental controls, environmental protection costs cannot be identified as additional costs, but simply affect the price and competitive market position of Arctic resources. They therefore do not appear as an identifiable increment to the cost that the Canadian consumer would have to pay for energy from the Arctic. In the Arctic, however, much of the background environmental assessment is undertaken at public expense and is not likely to be applied directly to the cost of energy from Arctic resources.

The Canadian iron and steel industry might have to spend an additional $40 million annually on pollution abatement to maintain desired environmental quality, and most of this can be ascribed to energy use. Such an expenditure might increase steel costs by about 2%. Increases of a similar magnitude can be estimated for the pulp and paper industry; however, an important part of these costs would be for abatement of water pollution, and cannot be charged against energy use.

An estimate of the expected costs of environmental protection in the various major energy activities in Canada shows that if practices are undertaken to ensure that during the next decade there is no deterioration of the environment from energy activities, while the amount of energy produced and used is doubled, the total additional cost, over and above the cost of producing the energy without environmental protection, would be of the order of magnitude shown in Table 1.

Such an expense represents an estimated increment of 5% to 7% in the overall cost of energy, and is about 0.5% of Canada's predicted cumulative gross national product for the period 1974-1983.

These additional expenses will be offset by benefits accruing from healthier humans, livestock and wildlife, reduction in crop loss and damage to vegetation, less corrosion and lower maintenance costs for buildings and machinery, increased and more stable property values, and cleaner and more attractive living and recreational areas. These benefits cannot be appraised directly in dollars; but few Canadians will doubt that their value will equal their cost. In addition, there is the vitally important benefit of pride and enthusiasm for their community and country when citizens live in, and consciously and at some expense maintain, a clean and attractive environment.

It should also be borne in mind that a significant proportion of the costs for environmental protection are once-only or incurred at infrequent intervals, while damage to the environment, if it occurs, tends to be long-lasting and may be permanent. A "clean" power station may produce power for thirty years without harming the environment, yet the cost for environmental protection will nearly all

be incurred when the station is originally installed; if the protection were not "built in", the effect of the damaged environment would be present, and the loss felt, year after year after year.

Table 1

SUMMARY OF ESTIMATED COST OF ENVIRONMENTAL PROTECTION, ENERGY ACTIVITIES

Period 1974–1983, assuming energy production and use doubles during this period

Transportation, and fuel used for transport (includes design changes, extra equipment, cost of reduced fuel efficiency, remedial or extraction processes)	$4–7 billion
Generation of electric power in stationary units (includes environmental surveys and assessment, re-design, control devices and practices, rehabilitation of land; also includes $1.0 billion for desulphurization of oil and expenses for fuel switching, which would be applied to only 20% of the total power generation capacity)	1.8 billion
Energy used for industrial and direct domestic purposes other than transport and electric power	0.7 billion
Environmental control within energy industries	0.5 billion
Total	$7–10 billion

Chapter 7

CONCLUSIONS

It is concluded that, with regard to production and use of energy in Canada:

Environmental quality must be achieved and maintained by designing and managing energy activities in the fullest practical knowledge of their environmental consequences, and by directly controlling the environmental impact.

Although improvement in technology is very desirable in many areas to improve the efficiency and economy of environmental protection, technology is known at present to achieve and maintain national objectives of environmental quality while still providing adequate energy for Canadian needs in the next three decades.

The cost of maintaining satisfactory environmental quality while considerable, will not likely disrupt the economy or in itself cause a fundamental change in the pattern of energy use.

It is feasible for costs of maintaining environmental quality including costs of environmental assessment and design to be met by direct increases in the cost of energy and energy-consuming products.

If Canadian energy or energy materials are exported, the payments received should compensate not only for the costs of environmental protection in the production of the energy or materials, but for any environmental costs of using alternate materials in the future due to absence of the exported resources.

Acceptable protection of the environment can only be achieved by the establishment of uniform objectives and guidelines for all of Canada. Within these national standards it will be necessary or advisable, to ensure further protection of the environment or to achieve economy and efficiency in the use of resources, to use practices or controls adjusted to different natural or industrial conditions in different parts of Canada. In areas of high environmental stress or severe industrial development it may be necessary to invoke regulations more severe than the national norm. In areas of special conditions of terrain, climate or biological development, or in critical offshore areas, it may be advisable to use a different mixture of environmental impact control practices than in the rest of the country. Uniformity of energy practice and equipment in all parts of Canada may result in higher costs and varying environmental benefits.

The long-term efficiency use of all of Canada's resources including energy resources, and economy and success in the maintenance of adequate environmental quality will require:

An effective program of land use in both undeveloped and developed areas;

A better understanding of environmental processes and ecological relationships in various parts of Canada;

A better understanding of demographic and social factors in Canada as they affect demands on energy;

Development of effective international environmental law.

Chapter 8

ESTIMATED COST OF AUTOMOBILE EMISSION CONTROLS

ESTIMATED COST* OF OPERATING AN AUTOMOBILE IN CANADA WITHOUT AND WITH EMISSION CONTROLS TO U.S. 1976 STANDARDS

	Without Controls Base Case[1] 1976	With Emission Controls to 1976 U.S. Standards
Cents/mile (1972 dollars)		
Ownership		
Depreciation	5.36	5.89[2]
Provincial Tax	0.27	0.30[2]
Finance Charges	1.04	1.14[2]
Insurance	1.21	1.27[2]
Licence Fee	0.26	0.26
Miscellaneous	0.40	0.40
Operating		
Gasoline	3.25	3.80[3]
Oil	0.20	0.20
Tires	0.54	0.54
Maintenance/Repairs	0.80	1.44[4]
	(cents) 13.33	(cents) 15.24
Dollars/Year (1972 dollars)	$1780	$2057
Increase		$ 277
Equivalent for "Compact" car		$ 219

*Based on information available February 1, 1973. Further information at time of going to press (April 25, 1973) suggests that with some techniques the additional cost may be slightly lower. The largest uncertainty is the future price of gasoline.

[1] Base case figures from study by Department of Supply and Services
Refer to: 4-door sedan

119" wheelbase
standard equipment
8 cylinder, automatic
power steering and brakes
Toronto location
13,500 miles/year
Trade-in every 4 years
(Compares with U.S. Department of Transport estimate of 13.6¢/mile for similiar basis.)

[2] Estimated that cost of 1976 emission control equipment (modified engine block and carburetor, dual catalysts) will add 10% to new car price. White House Office of Science and Technology report indicates the following:

Average of reporting U.S. auto manufacturers:	$500 per car
U.S. regulatory agencies estimate:	$350 " "

Depreciation, Provincial tax, and finance charges, are all directly proportional to initial cost and will increase by 10%.
Insurance is assumed to increase by 5%, to cover portion related to vehicle replacement.

[3] Gasoline costs are expected to increase due to:

(i) Gasoline price increase of 1¢/gallon;

(ii) 15% reduction in mileage per gallon.

Gasoline price increase based on White House Office of Science and Technology report, and confirmed by W. L. Nelson estimates. This price increase is difficult to ascertain but is not a major percentage of the overall cost increase.

The 15% reduction in miles per gallon is based on automotive industry estimates obtained directly. Ethyl Corporation estimates are higher.

[4] Maintenance and repairs are estimated to increase proportionally to initial cost. In general, pollution control equipment has required additional maintenance more than proportional to the added cost, but this trend may be modified in time. In addition, cost of catalyst replacement if included is estimated to be $100 every 18 months for the General Motors systems.

APPENDIX B

APPENDIX B

PART 1. ECONOMIC VIABILITY OF THE ENERGY DEVELOPMENT CASES

ECONOMIC VIABILITY OF THE ENERGY DEVELOPMENT CASES

The objective of this appendix is to present the results of an empirical study of the impact of the different energy cases discussed in Section IV of the main report on Canada's medium term economic performance through to 1980. An important feature of the analysis is the attempt to identify where pressure points might develop in the economic system's attempt to accommodate the different resource development cases. The economic impacts discussed are conditional upon the background economy on which the investments are imposed. It is difficult to perceive precisely what direction the Canadian economy might take through to 1980, and as will be pointed out in the analysis, the results should be viewed as order of magnitude indicators only.

The economic impact of the operations phase of suggested energy projects —when the investment is completed and production begins—is not dealt with quantitatively in this section because most of the envisaged projects will not be producing until after 1980; presently beyond the time frame of the econometric model. The formation of an energy policy is, however, clearly incomplete without responses to the hard questions about the long-term benefits of allocating present resources to the energy economy. A discussion of the general concerns in developing a Canadian energy policy has been given in the main report and it is the narrower question of medium-term economic impact to which this section of the report addresses itself. The regional impact of the different options and related social and environmental costs, though important, are beyond the scope of this study.

Methodology

To quantify the economic impact through the 1970's of the alternative energy development strategies, it is necessary to have a dynamic macro framework of the Canadian economy and a projection of a possible course for the period 1973-80. In choosing to quantify the medium-term implications of resource development the possibility of such programs generating short-term problems not observable in the analysis, needs to be pointed out. In order to perform the analysis of alternative resource investment patterns, basic information was required on total costs broken down by broad input categories for the various cases. The next steps were to discuss the availability of such inputs and then to establish the transmittal order of market response within the context of a national economic system.

The recently developed CANDIDE September model was accepted as the most appropriate medium-term model of the Canadian economy.[1] CANDIDE is an annual, medium-term model which is both comprehensive and disaggregated. It has the added advantage of incorporating input/output matrices which permit analysis of a great deal of industrial detail not available with most other econometric models of the Canadian economy. At the same time, the present version of the model appears to have certain important limitations. There are areas which are somewhat less well developed, notably the financial and external sectors, and there are some causal relationships which may be questioned, particularly some of the cost-price equations which seem to be relatively insensitive to variations in aggregate demand. In the following material, care is taken to point out where there are reservations about the results being generated by the model. On the whole, however, the simulation work produced results which appear to be internally consistent.

A basic control solution for the CANDIDE September model[2] was used in this study to provide the required projection of the economy over the period 1973 to 1980 against which to measure the impact of the various energy development cases. The CANDIDE projections are based on a series of equations expressing the interrelationships of the different economic variables which in turn are based on accepted theory and estimated from historical data for the period 1955 to 1970. These observed structural relationships are assumed to persist through to 1980 or at least change in a pattern based upon extrapolation of past trends. The control solution also involves a number of assumptions as to the behaviour of the over 300 exogenous variables in the model. One of the main assumptions is that there will be a favourable international environment for economic growth. Specifically, the average rate of growth of real GNP in the United States is anticipated to be 4½ per cent which, when combined with expected strong growth in Japan, Western Europe, and some improvement in the United Kingdom, is thought will provide for strong growth in Canadian exports through the decade. The control solution also assumes that there will be no change in nominal tax rates and that there will be moderate increases in government expenditures.

The economic climate in which the different energy cases would proceed, therefore, is thought to be marked by a continuation of the high rates of growth in real output and employment that marked the 1960's. Demand activity is projected to be relatively strong at the start of the period and peak again in 1976. Strong growth in both public and private investment is anticipated. There is expected to be only a slight decrease in the rate of growth of output per person employed and the rate of growth in total employment is thought to be only slightly less than in the 1960's. In this setting, real disposable income will advance at about the same pace over this decade as in the 1960's given unchanged nominal tax rates and productivity gains. As the rate of population growth is forecast to decline in the 1970's,

[1] Refer to McCracken, M.C. *An Overview of CANDIDE 1.0*. Published by Economic Council of Canada, 1973, for documentation on the structure and development of CANDIDE Model 1.0

[2] This control solution should not be misconstrued either as being a forecast of Canadian economic performance by the Economic Council of Canada, or as being selected as the single most probable development. It is simply a background simulation of a possible course for the economy.

this will mean a substantial increase in the rate of growth of real disposable income per capita.

On the policy question of unemployment, the unemployment rate which averaged 5 per cent during the 1960's, is projected to be only marginally lower because of an expected slight decline in the rate of growth of the labour force. As to price performance, the average rate of increase of the GNE price deflator over the period is projected to decline significantly from the 3.3 per cent average advance during the 1960's to around the 2.75 per cent level. This improvement in price behaviour is explained by a more stable growth pattern for investment in the 1970's, a slower rate of increase in export prices and the assumption of no change in indirect tax rates. Because of certain questions associated with the model's price behaviour assumptions, *the analysis in this study focuses on the marginal impact of the energy options relative to each other rather than on absolute levels.*

The "accuracy" of this projection has an important influence on the net medium-term benefits that might accrue to the economy. The relative impacts of the particular alternative energy cases can be argued to be dependent on both the level of activity and the cyclical phase of the economy when they proceed. Generally, economic reasoning suggests that the shorter-term gains on output and employment from the large energy projects would be maximized, and pressures on prices and consequent stresses on the existing pattern of resource allocation would be minimized, if such projects could proceed when there is substantial slack in the system. It is equally true, however, that under tighter market conditions, it can be reasoned that the price pressures associated with the energy development options might be more substantial.

The basic September model projection also contains an implicit estimate of the total capital requirements of the energy sector. Analysis of the projection suggests a figure in excess of 46 billion current dollars. Annexe 1 shows its distribution over the decade, while the notes to Annexe 1 provide, in some detail, a discussion of the derivation of this estimate from the industry-level investment equations in CANDIDE.

To assess the impacts of the different energy investment scenarios on the overall performance of the economy, the control solution projection of gross fixed capital formation in the energy sector was adjusted. This allowed for the simulation of investment scenarios A to E. For the Self-sufficiency case (Case A), total energy sector investment was decreased by more than 4.6 billion constant dollars; for Cases B,C,D and E, the energy investment totals were increased by 2.5, 7.7, 13.5 and 1.6 billion constant dollars respectively. The distribution of these adjustments over the decade is shown in Annexe 2.

Certain equations in CANDIDE were also modified. Specifically the commodity composition of the capital expenditures for both the petroleum and pipeline industries were altered to reflect the higher transportation costs of frontier area development. Annexe 3 shows the investment increments for northern resource development and the adjustments made. The notes to Annexe 3 describe the adjustment in further detail.

In addition, adjustments were made to the capital requirement projections for the petroleum industry in the five development cases to reflect additional expenditures for geological and geophysical activities. While expenditures of this

type are usually considered as an operational expense (as they are in the input-output model in CANDIDE) in this particular study they are treated as a capital expenditure item as they form an important ingredient of frontier development costs. Annexe 4 shows the absolute amounts involved with the different cases.

An adjustment was also required to the assumed growth pattern of hydrocarbon exports in the control solution. The massive expenditures on the development of Arctic resources and transportation systems clearly have implications for the size of exports, especially beyond 1980. For the 1970's, three export scenarios were developed. For Case A, the Self-sufficiency case, it was assumed that the presently authorized exports of natural gas would continue, but that there would be no further export licenses approved. The growth of oil exports was also curtailed to the point where it offset projected oil imports to Eastern Canada. Consequently, a downward adjustment to the projection of hydrocarbon exports was required. For Cases B, C and D, the construction and completion of a northern gas pipeline shortly after the middle of the decade was assumed to increase natural gas exports above the projection of the control solution. These increases, however, are thought to be accompanied in each case by some reduction in the growth of oil exports. For Case E, the delay in the completion of a gas pipeline until the end of the decade leads to a reduction in the volume of gas exports below those of Cases B, C and D. Annexe 5 relates the projections of hydrocarbon exports for the different energy development cases.

As Canada has no experience with pipelines of the size and nature proposed in the frontier areas, a series of simulations was also run to assess the relative impacts of Cases B to E on Canadian economic performance if higher volumes of foreign goods and services are used to satisfy the pipeline construction requirements.

The observed historical average proportion of Canadian content in pipeline construction reflected in CANDIDE, appears relatively high. The special problems relating to large diameter northern pipelines suggest that a Canadian content of between 50 and 60 per cent may be more realistic for pipeline construction in the frontier areas during the 1970's.

Annexe 6 shows the import adjustments made assuming a low level of Canadian content in the goods and services required for pipeline construction. The notes to Annexe 6 further elaborate on the adjustments made to CANDIDE.

The CANDIDE September model was first used with a fixed exchange rate system. A series of simulations was run with an endogenous exchange rate variable and different combinations of the Canadian content of pipeline and foreign financing assumptions in an attempt to determine the influence of these variables. The balance of payments sector of CANDIDE is, however, not yet well developed. One important deficiency is that it does not presently allow the determination of any feedback effects of exchange rate variation on domestic production, domestic prices or the current account. Therefore, the study has not been able to deal directly with the important question of the impact of the different energy cases on the exchange rate and on the price competitive position of Canadian export and import-competing industries. Notwithstanding the foregoing, as a general economic principle it can be asserted that the required change in the terms of trade because of the energy development projects could come through as a greater rate of increase in the GNE price

deflator than would be the case if the exchange rate was allowed to respond to market forces.

The following discussion refers to specific numbers, reflecting the results provided by the model. The reader should, however, recognize that projections can never be that exact and econometric models are not error free. The snapshot of the economy to 1980 implied in the September model control solution may become inappropriate as the time for decisions on the pipeline approach. The state of the art can be expected to advance; but at this time and from this perspective the best that can be done is to subject the results of the work to certain tests of reasonableness and evaluate them in the light of the historical performance of the Canadian economy. The empirical results offer a valuable insight into the potential economic impact of the selected energy development cases.

Comparative Analysis of the Economic Viability of Energy Development Cases

Impact on Gross National Product

Gross national product is projected in the macro base control solution to reach the \$180 billion level by 1980, as compared to a GNP of \$85 billion in 1970. In 1961 constant dollars, the corresponding GNP totals are \$105 billion in 1980 and \$63 billion in 1970. Any increase in energy capital expenditures above the \$47 million figure implicit in the control solution projection for the decade would further stimulate aggregate demand in the economy. A high and stable rate of growth in output and employment is an important economic goal in our economy. To the extent that increased energy development utilizes underemployed resources in the economy, important output and employment gains would accrue to the country. At the same time, it is important that the realization of a higher rate of economic growth does not generate excessive pressures that would divert the economy from attainment of other goals such as reasonable price stability, an equitable distribution of income, and protection of the environment.

The extent to which market disruptions or price changes occur with the different energy options will depend upon the nature of the development package and the state of the economy. What is the geographic distribution of the energy projects, what are their labour and raw material requirements and is there any excess capacity in these particular markets and in the economy in general? Even in these most adverse circumstances the required basic resource reallocation has important positive effects which the government will have to weigh against any social and/or economic costs involved in the displacement of output and employment in particular industries. The patterns of growth in real GNP generated by the control solution and by the different cases for the period 1973-80 are illustrated in Charts 1 and 2.

With no modifications for variation in the level of Canadian content for pipeline construction, shocking the model with the anticipated shortfall in energy investment of Case A, the Self-sufficiency Development case could, under certain circumstances, lead to a reduction in real GNP of about \$11 billion from the

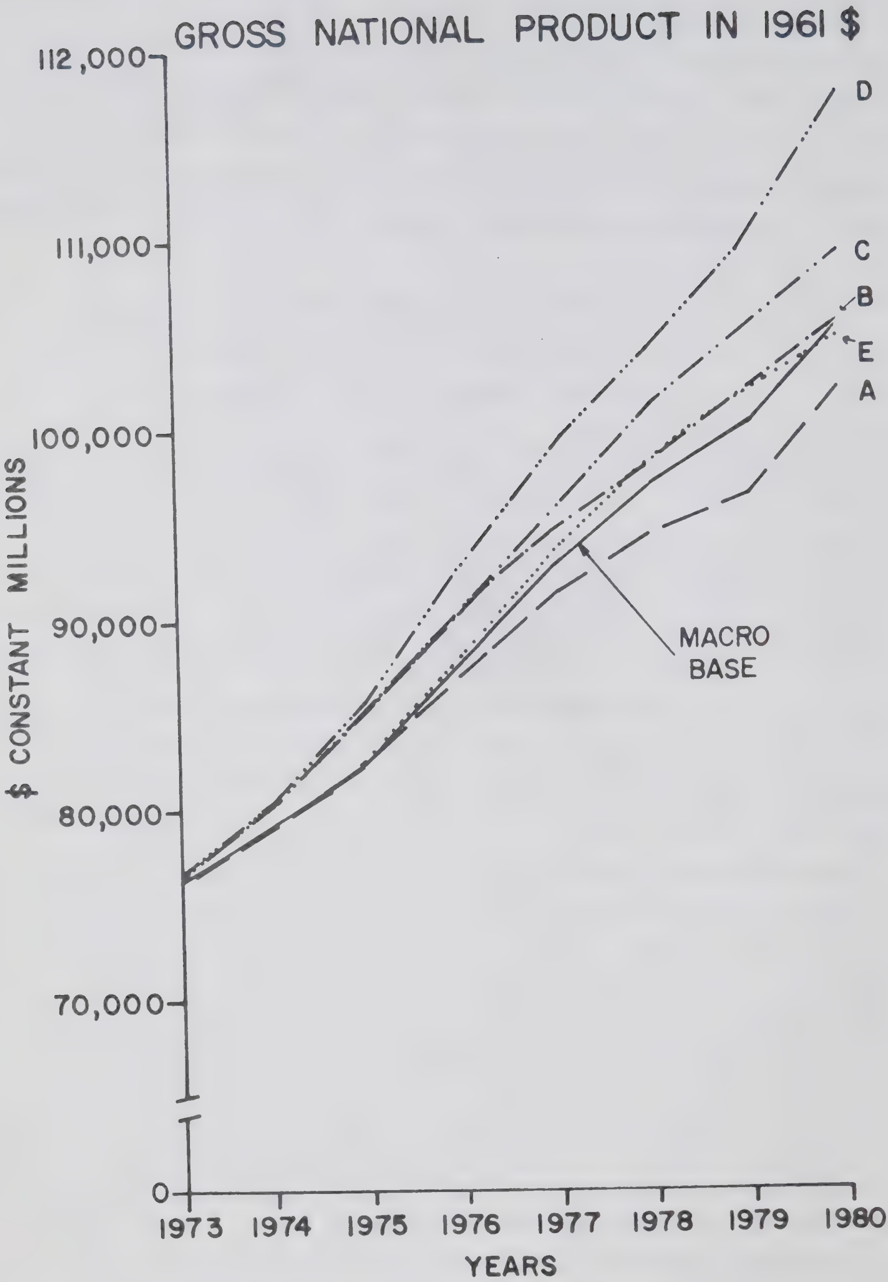

GROSS NATIONAL PRODUCT IN 1961 $
112,000
111,000
100,000
90,000
80,000
70,000
0
$ CONSTANT MILLIONS
D
C
B
E
A
MACRO
BASE
1973
1974
1975
1976
1977
1978
1979
1980
YEARS

Chart 1

CHART 1

GROSS NATIONAL PRODUCT IN 1961 $

	Historical Normal (Macro base)	Self-sufficient Development (Case A)	Standard Development (Case B)	Extensive Development (Case C)	Maximum Development (Case D)	Delayed Development (Case E)
1973	76,379	76,602	76,643	76,643	76,641	76,643
1974	79,209	79,200	80,289	80,320	80,300	79,364
1975	82,580	82,354	85,262	85,293	85,915	82,815
1976	87,871	87,019	90,774	90,900	93,120	87,964
1977	93,069	91,583	94,789	95,850	99,351	93,676
1978	97,165	94,560	98,067	101,262	104,271	98,695
1979	100,851	97,674	101,760	106,392	109,819	101,884
1980	105,311	102,074	105,665	109,101	117,429	104,777
Average rate of increase (1973–1980)	4.99	4.59	5.04	5.46	6.43	4.93

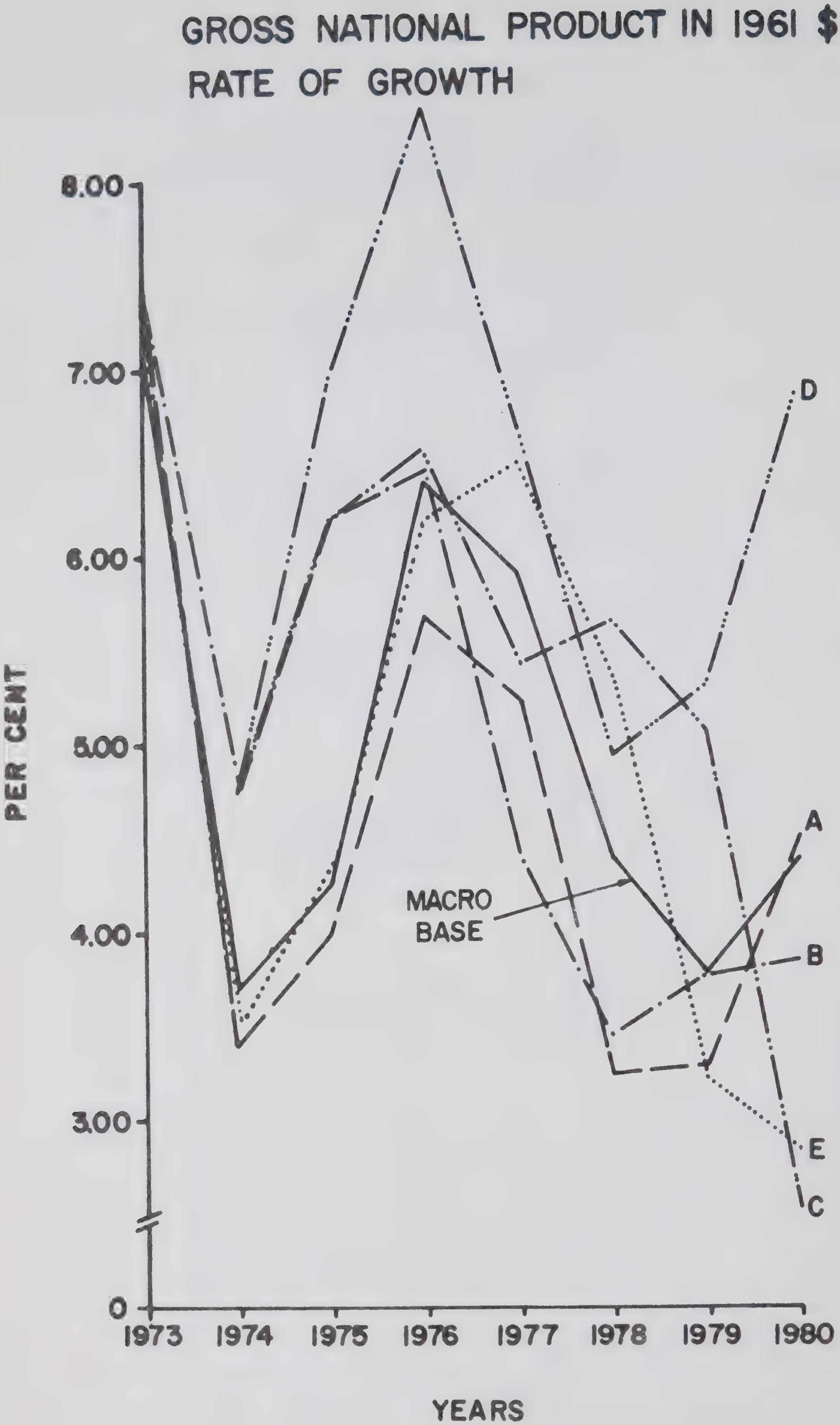

GROSS NATIONAL PRODUCT IN 1961 $
RATE OF GROWTH
8.00
7.00
6.00
5.00
4.00
3.00
0
PER CENT
D
A
B
E
C
MACRO
BASE
1973
1974
1975
1976
1977
1978
1979
1980
YEARS

Chart 2

CHART 2

GROSS NATIONAL PRODUCT IN 1961 $—RATE OF GROWTH

	Historical Normal (Macro base)	Self-sufficient Development (Case A)	Standard Development (Case B)	Extensive Development (Case C)	Maximum Development (Case D)	Delayed Development (Case E)
1973	7.05	7.37	7.42	7.42	7.42	7.42
1974	3.71	3.39	4.76	4.80	4.77	3.17
1975	4.26	3.98	6.19	6.99	6.99	5.45
1976	6.41	5.67	6.46	6.57	8.39	6.22
1977	5.92	5.24	4.42	5.45	6.69	6.49
1978	4.40	3.25	3.46	5.65	4.95	5.36
1979	3.79	3.29	3.77	5.07	5.32	3.23
1980	4.42	4.50	3.84	2.55	6.93	2.84
Average rate of Increase (1973–1980)	4.99	4.59	5.04	5.46	6.43	4.93

projections of the macro control solution. With this case, the associated capital requirements actually are $5 billion lower than the projections of the macro base and the exports of hydrocarbons are also substantially reduced from their historical growth projections. The patterns of growth in real output and in total investment with Case A are similar to those generated by the control solution through to 1977. In the last four years of the decade, the deflationary effects of the shortfall in investment, however, accumulate and are reflected in the emergence of considerable slack in the economy. In view of the delays in the response of aggregate demand to price developments, including the exchange rate, which would improve the competitive position of different industries over time, expansionary fiscal and monetary policies would appear necessary to maintain aggregate demand at levels consistent with growth and employment objectives. The existence of attractive alternatives for Canadian savings may suggest the possibility that no net decreases in investment need take place. The impacts discussed above are predicated solely on the assumption that Canadians might have no alternatives to resource development to consider. This is obviously not the case. The important conclusion to be extracted from the above numbers is the order of magnitude of the economic slowdown to be created should Canadians be unable to pursue alternative vehicles of growth.

The incremental capital expenditures of Case B, the Standard Development case, generated an additional $11 billion in real GNP over the period, most of which is explained by the construction of the Mackenzie Valley natural gas pipeline and the related income generation. The rate of real growth with Case B peaks in 1975 and 1976 during the pipeline construction period and then moderates significantly in the second half of the decade. This growth pattern tends to lead by one year the growth pattern exhibited by the control solution and it is conditioned by the relatively slow rates of real growth observed in the control solution during 1974 and 1975. Alternative background solutions would modify the results.

With Case C, the Extensive Development case, the adjustment in total real output over the period is significantly larger than with Case B, being approximately $23 billion. The implicit income multiplier, however, is lower for Case C than for Case B because by terminating the study period in 1980, some of the lagged income effects from construction of the Mackenzie Valley oil pipeline in 1978-79 are excluded. The price and employment indices indicate that there appears to be some constraint imposed by the limits of the economy's productive capacity, notably in 1979. With this case, the rate of real growth peaks in 1975-76 and again in 1978, corresponding to peaks in investment activity related to the construction of the two northern pipelines. If the period 1977-79 should actually develop as shown in the control solution to be a time of relatively slow growth, the construction of a Mackenzie Valley pipeline could provide an important stimulus. An alternative background simulation lacking this cyclical feature would generate a somewhat different picture of the economic impact.

In Case D, the Maximum Development case, the increments to real GNP over the period approach $44 billion. Again, the full income-generating effects of the different projects constructed in the latter part of the decade would not have worked their way through the economy by 1980. But more important,

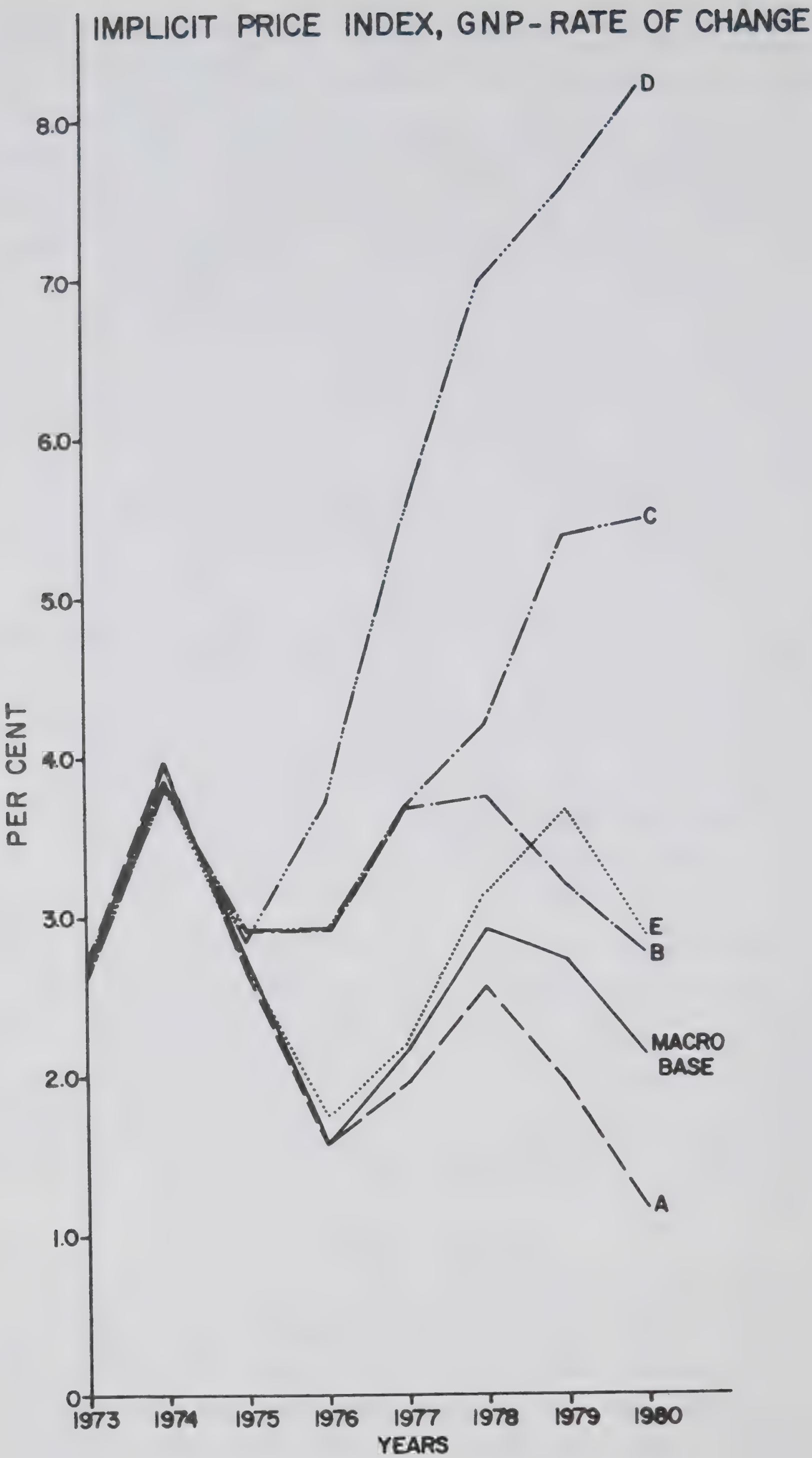
in the late 1970's real growth would clearly be constrained by full capacity in the economy. The growth in total investment and particularly in non-residential construction associated with Case D exhibits a less volatile pattern than that observed in Cases B and C, but at considerably higher levels. Such high investment growth appears to be unsustainable in the 1980's. Only in an economy operating at a radically lower level than the macro base solution would the concentration of such large projects in such a short period be considered as feasible. In addition to the limitation of energy resources, this volatility in investment activity would precipitate a boom and bust growth pattern. The lengthening of the investment phase of this case into the 1980's might appear to ameliorate the shorter-term adjustment problems and provide continuing and more stable market opportunities for Canadian suppliers of energy development.

Under Case E, Delayed Development, the increments to real output over the decade are only slightly more than $3 billion. The reason for the difference in the impact on real output with that observed in Case B is that delay in the construction of the Mackenzie Valley gas pipeline is such that the income multiplier effects of that project do not all come through before the end of the study period. Furthermore, the delay in pipeline construction has also led to some curtailment of exports below those anticipated in Cases B through D.

When it is assumed that the level of Canadian content in pipeline construction would be lower than that implicit in CANDIDE's observed historical relationship, the stimulus to the economy of increased energy expenditures is proportionately less. For example, with Case B and a low (50%) level of Canadian content, the increments to real GNP over 1973-80 decline to $7 billion from the $11 billion generated with the higher historical level of Canadian content. The divergence in the patterns of real growth for Case B and for the control solution narrow with the lower levels of Canadian content, particularly during the construction of the pipeline. Under Case C, the assumption of lower levels of Canadian content has a greater relative impact on real growth than Case B, for example, because of the presence of a Mackenzie Valley oil pipeline. The associated increase in real output over the period with this case, declines from $23 billion to $16 billion with the assumption of a 50 per cent level of Canadian content in pipeline construction. The lowering of Canadian content requirements appears useful, therefore, in moderating the stress associated with pipeline construction in high demand periods. The average annual rate of real growth with the lower levels of Canadian content would still remain significantly above the 5 per cent average growth rate estimated in the macro base control solution.

Impact on Prices

As discussed above, the impacts of Cases A to E on domestic prices will depend largely on the degree to which the specific energy projects have to compete for their labour, material and capital requirements in particular domestic markets, and the availability of foreign sources of supply. The upward pressures on prices are, of course, greatest when the energy projects must compete in relatively tight domestic markets for their factor inputs and they do so only by driving up prices to attract the required development inputs away from



IMPLICIT PRICE INDEX, GNP-RATE OF CHANGE
PER CENT
YEARS
0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
8.0
1973
1974
1975
1976
1977
1978
1979
1980
D
C
E
B
MACRO BASE
A

Chart 3

CHART 3

IMPLICIT PRICE INDEX, GROSS NATIONAL PRODUCT—RATE OF CHANGE

	Historical Normal (Macro base)	Self-sufficient Development (Case A)	Standard Development (Case B)	Extensive Development (Case C)	Maximum Development (Case D)	Delayed Development (Case E)
1973	2.72	2.63	2.63	2.63	2.63	2.63
1974	3.85	3.98	3.83	3.83	3.83	3.83
1975	2.65	2.68	2.91	2.93	2.84	2.67
1976	1.55	1.58	2.92	2.92	3.75	1.75
1977	2.17	1.94	3.69	3.69	5.54	2.19
1978	2.91	2.56	3.74	4.20	7.00	3.16
1979	2.74	1.96	3.20	5.39	7.54	3.62
1980	2.13	1.19	2.79	5.47	8.20	2.88
Average rate of increase (1973–1980)	2.59	2.32	3.21	3.88	5.17	2.86

existing or alternatively proposed economic endeavours. The patterns of movement in the GNE price deflator projected for the macro base control solution and the different energy cases are presented in Chart 3 for the period 1973-80. Explicit consideration of regional price pressures has not been undertaken in this study although empirical studies suggest that regional price pressures tend to be spread quickly throughout the economy.

With the hypothesized reduction of energy investment of the Self-sufficiency Development case, the model generates a decrease in the average rate of price increase for 1973-80 of .3 per cent below that of the control solution. Much of the deceleration in price advance is observed in the late 1970's as the cumulative effects on growth of the lower energy investment totals and a restricted export policy become substantial. This declaration is, as noted earlier, predicated on an assumed reduction in net investment occurring if resource development is restrained. Indeed, the release of scarce factors of production from the energy economy for use in other productive endeavours might be regarded as a benefit if more attractive investment opportunities are present. It is not certain that a necessary consequence of pursuing a self-sufficiency approach will mean a reduction in total investment or real growth.

With no structural modification for variation in the level of Canadian content in Case B, the model generates a .6 percentage point upward movement in the average rate of price increase projected by the control solution for the study period. The behaviour of prices in Case B diverges significantly from that of the control solution only under the influence of pipeline construction. Price advances in 1976 and 1977 exceed those of the control solution by 1.3 and 1.5 per cent respectively. The upward price pressures associated with a Mackenzie Valley gas pipeline would occur at a time when the rate of price increase is thought to be moderating after a cyclical peak in 1974. A different base solution with a cyclical pattern where price pressures peak during the proposed construction period would modify both the results and conclusions.

The construction of a major oil pipeline along the Mackenzie Valley in 1978-79, anticipated in Case C, would produce further pressures on prices at a time when the control solution suggests that the rate of increase in prices would again be declining after a cyclical peak in 1978. Under conditions of accelerating prices, the inflationary pressures of a second major pipeline would be even greater. In point, in 1979 and 1980 the projected rates of price increase exceed the rates of increase of the GNE price deflator in the control solution by 2.7 per cent in 1979 and 2.4 per cent in 1980; but the overall price performance would certainly be more disconcerting if the second Mackenzie Valley pipeline would be undertaken one or two years earlier. Over the period, this case is thought to add more than a full percentage point to the average annual rate of price increase.

With the Maximum Development case, Case D, the stress on the country's resources associated with the large increase in energy investment envisaged is clearly evident in the behaviour of prices. With this case, the model generates an average rate of increase for the GNE price deflator which is twice that of the control solution. Moreover, after 1978 the rate of price increase accelerates, and in 1980 it is almost four times that of the control solution.

Finally, with the Delayed Development case, Case E, the price behaviour is similar to that of the control solution to 1978 when some divergence occurs because of price pressures associated with construction of the Mackenzie Valley natural gas pipeline in 1978-79.

With the assumption of lower levels of Canadian content in pipeline construction, some of the upward price pressures associated with these capital expenditure programs are, of course, moderated through the implied decrease in demand for Canadian inputs. Perhaps more important, this moderating influence is most marked in the two pipeline construction periods. There is some moderation in the rates of price increase in 1976-77. Under Cases B and C, for example, the rate is lowered from between 1.25 and 1.5 per cent to 0.75 and 1 percentage points above the control solution projection. In 1979-80, the impact on price performance from lower Canadian content requirements with Case C, appears to be even more significant as the potential price increases would be reduced by 1.3 and 1.5 percentage points in 1979 and 1980 respectively. With the Maximum Development case, the alleviation of inflationary pressures is more pronounced as the assumption of low Canadian content would reduce the average rate of price increase over 1973-80 by a full percentage point to approximately 2 percentage points above the macro base.

This discussion of prices must be emphasized as carrying even more than the usual caveats. As already noted, reservations are held regarding the sensitivity of prices in the CANDIDE model to variations in aggregate demand.

Impact on the Unemployment Rate

In the recent past, the Canadian economy has not at any time moved towards full employment while at the same time experiencing a moderation in the pace of price advance. While it is generally accepted that there exists some form of trade-off between the attainment of unemployment and price objectives, it is also true that the links between unemployment levels and rates of domestic price increases are complex and indirect. Insofar as increased energy development generates growth in real output and employment, the pool of unemployed human resources in the system would be depleted. This depletion would be accompanied by upward pressures on wages in the economy and eventually, through complex wage-price links, would lead to upward pressures on end-product prices. While the utilization of unemployed resources might be viewed as an unambiguous benefit, the shifting of resources from situations of underemployment is not without certain social and economic costs. These costs are perhaps more important if the shifts are for transitory construction projects. The costs of drawing upon finite supplies of unemployed resources and of resource reallocation can generate increases in general prices which would hinder the ability of other industries to compete in domestic and world markets and thereby reduce their ability to sustain a given labour force. This is of course true of any major investment program. This might also exacerbate certain regional employment problems given the possibility of limited alternative employment opportunities as discussed earlier. It is conceivable that the implementation of the different energy cases might lead to a reduction in available unemployed human resources past

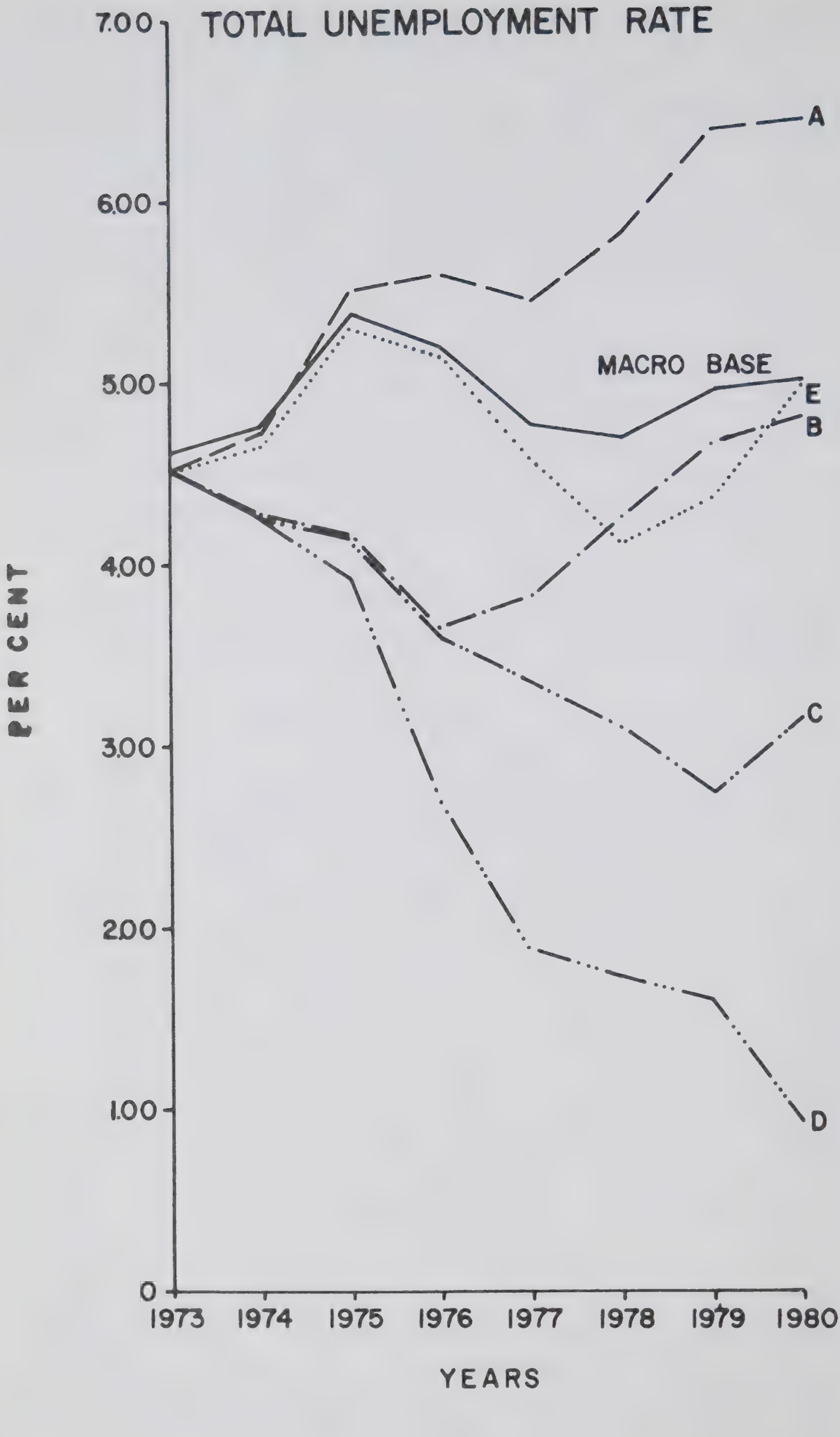

TOTAL UNEMPLOYMENT RATE
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0
PER CENT
A
MACRO BASE
E
B
C
D
1973
1974
1975
1976
1977
1978
1979
1980
YEARS

Chart 4

CHART 4

TOTAL UNEMPLOYMENT RATE

	Historical Normal (Macro base)	Self-sufficient Development (Case A)	Standard Development (Case B)	Extensive Development (Case C)	Maximum Development (Case D)	Delayed Development (Case E)
1973	4.62	4.52	4.52	4.52	4.52	4.52
1974	4.77	4.73	4.29	4.27	4.28	4.66
1975	5.38	5.50	4.17	4.15	3.93	5.29
1976	5.20	5.58	3.66	3.61	2.72	5.14
1977	4.76	5.45	3.72	3.36	1.88	4.56
1978	4.70	5.82	4.26	3.11	1.73	4.12
1979	4.95	6.38	4.67	2.77	1.60	4.36
1980	5.02	6.44	4.82	3.16	.94	4.97
Average rate of growth (1973–1980)	4.93	5.55	4.26	3.62	2.70	4.70

the point where further demands for labour might impair the productive efficiency of the economy. It is this point which is usually defined as the full employment target level. The indicated movements of the unemployment rates from 1973 to 1980 for the control solution and for Cases A to E are shown in Chart 4.

With no modification for variation in Canadian content, the control solution projects an unemployment rate hovering around 5 per cent throughout the period. With the Standard Development case, Case B, there appears to be a .6 percentage point gain on the average level of unemployment indicated by the control solution for the period 1973-80. This is largely explained by the stimulus to employment growth of the Mackenzie Valley natural gas pipeline. In both 1976 and 1977, the unemployment rate drops below 4 per cent indicating some tightness in labour markets, particularly the supporting pipeline construction. From 1977 the unemployment rate under Case B gradually increases to about 4.75 per cent by 1979-80. The overall gains in employment might also be viewed as a measure of the potential resource reallocation which would be requisite under conditions of full employment.

Under the Extensive Development case, Case C, the average reduction in the rate of unemployment from that indicated in the control solution is projected to be over 1.25 per cent. The pattern of unemployment in Case C follows that of Case B into 1977, but then continues to decline under the influence of the second Mackenzie Valley pipeline to a low of under 3 per cent in 1979. This decline is accompanied by sharp increases in the rates of wage and price advances in 1979-80. These increases are a reflection of the depletion of available unemployed factors of production in relatively tight supply conditions.

Under the Maximum Development case, Case D, the average rate of unemployment is below 3 per cent for the period, and well below realistic full-employment target levels. In 1979-80, unemployment is projected to be well under 2 per cent and accompanied by rates of price increases quadruple those of the control solution. Such a combination is suggestive of a need for a substantial resource reallocation and these conclusions would appear to be independent of the type of background simulation used as a control. With the Delayed Development case, Case E, the rate of unemployment follows closely that of the control solution through 1977 before decreasing sharply with the construction of a Mackenzie Valley natural gas pipeline.

Finally, in the absence of compensatory government expansionary measures, the average unemployment rate over the decade for the Self-sufficiency case, is about 0.5 percentage point above the control solution average rate of 5 per cent. The movement in the unemployment rate with Case A is above that of the control solution throughout the period and is below 5 per cent in only 2 years. Such rates of unemployment exceed acceptable limits and might require active intervention by the government to stimulate aggregate demand, especially if alternative investment opportunities are not present.

With the assumption of lower levels of Canadian content in pipeline construction, the gains on unemployment or alternatively the possible size of the required resource reallocation are reduced. With Case B, for example, the average level of unemployment increases to 4.5 per cent with the low level of Canadian content from 4.3 per cent with the historical level of Canadian content. With Case

TABLE 1

	1961–70	1973–80					
		Macro base Development	Self-sufficient Development (Case A)	Standard Development (Case B)	Extensive Development (Case C)	Maximum Development (Case D)	Delayed Development (Case E)
	(Average Annual Percentage Change)						
Major Macro Indicators							
Real Gross National Product	5.2	5.0	4.6	5.0	5.5	6.4	4.9
GNP Price Deflator	3.3	2.6	2.3	3.2	3.9	5.2	2.9
Consumer Price Index	2.5	2.3	2.1	2.8	3.2	4.1	2.5
Total Employment	3.1	2.8	2.4	2.9	3.3	4.5	2.8
Average Rate of Unemployment	5.0	4.9	5.5	4.3	3.6	2.7	4.7
Output per Person Employed	2.3	2.1	2.1	2.0	2.0	2.3	2.0
Disposable Personal Income—$ 1961	5.1	5.1	4.5	5.3	6.2	7.8	5.2
Major Demand Component Indicators; (Constant 1961–$)							
Consumer Expenditure	4.9	4.8	4.4	5.1	5.7	7.1	4.8
Government Current Expenditures	5.1	4.4	4.1	4.5	4.9	5.3	4.4
Government Fixed Investment	4.9	4.6	4.6	4.7	4.7	4.6	4.7
Business Fixed Investment:							
Residential Construction	4.3	3.2	2.8	3.0	2.9	3.1	3.2
Non-residential Construction	5.2	7.2	5.5	6.8	8.9	10.8	7.8
Machinery and Equipment	8.2	8.1	6.8	7.7	9.0	10.9	7.9
Major Monetary Indicators							
Average Yield for Ten Industrial bonds	6.7	7.2	7.2	7.3	7.4	7.5	7.2
Monetary Aggregate: Currency and Demand Deposits Held by the Public	5.8	6.7	6.0	7.3	8.4	10.7	6.9
Total Personal Savings as a Proportion of GNP	4.0	4.8	4.6	5.1	5.5	6.1	5.0

TABLE 2

SUMMARY OF IMPACT OF CASE A (SELF-SUFFICIENT DEVELOPMENT)

Items	Years				
	1976	1977	1978	1979	1973–1980
(1) *Decrease* in Capital Expenditures Billions of Constant $	.3	.3	.6	.6	*3.3*
(2) Rate of growth in real GNP, per cent					
(a) case A	5.7	5.2	3.3	3.3	*4.6*
(b) base projection	6.4	5.9	4.4	3.8	*5.0*
(3) Rate of growth implicit price index of GNE, per cent					
(a) case A	1.6	1.9	2.6	2.0	*2.3*
(b) base projection	1.6	2.2	2.9	2.7	*2.6*
(4) Unemployment rate, per cent					
(a) case A	5.6	5.4	5.8	6.4	*5.5*
(b) base projection	5.2	4.8	4.7	5.0	*4.9*
(5) Rate of increase in money supply in per cent					
(a) case A	6.6	6.4	5.3	4.8	*6.0*
(b) base projection	7.2	7.2	6.7	6.0	*6.7*
(6) Average yield on industrial bonds, per cent					
(a) case A	7.3	7.1	7.0	6.9	*7.2*
(b) base projection	7.3	7.2	7.1	7.1	*7.2*
(7) *Decrease* in total employment, thousands of man-years					
(a) case A	45	98	176	250	*846*
(8) Marginal Percentage *decreases* in real domestic product of industrial sectors					
(a) iron and steel	3.0	4.6	9.1	.7	*3.7*
(b) metal fabricating	2.4	3.4	5.3	5.5	*3.1*
(c) manufacturing	.8	1.3	2.2	2.2	*1.1*
(d) construction	2.0	3.1	5.5	5.9	*3.0*
(e) transportation	1.4	2.2	3.4	4.0	*2.0*
(f) service	.5	1.1	1.8	2.6	*1.1*
(g) trade	1.1	1.8	3.1	3.5	*1.7*
(9) *Decreases* in employment by industrial sector, thousands of man-years					
(a) manufacturing	10	17	29	37	*137*
(b) service	7	18	35	58	*189*
(c) construction	8	14	23	29	*114*
(d) transportation	3	12	19	26	*86*

TABLE 3

SUMMARY OF IMPACT OF CASE B (STANDARD DEVELOPMENT)

Items	1975	1976	1977	1973–1980
(1) Additional Capital Expenditures Billions of Constant $..	1.5	1.5	.3	*2.2*
(2) Rate of growth in real GNP, per cent				
(a) case B high	6.2	6.5	4.4	*5.0*
(b) case B low	5.5	6.4	4.9	*5.0*
(c) base projection	4.3	6.4	5.9	*5.0*
(3) Rate of growth implicit price index of GNE, per cent				
(a) case B high	2.9	2.9	3.7	*3.2*
(b) case B low	3.0	2.6	3.2	*3.1*
(c) base projection	2.6	1.6	2.2	*2.6*
(4) Unemployment rate, per cent				
(a) case B high	4.2	3.7	3.7	*4.3*
(b) case B low	4.5	4.1	4.0	*4.5*
(c) base projection	5.4	5.2	4.8	*4.9*
(5) Rate of increase in money supply in per cent				
(a) case B high	9.4	8.8	7.5	*7.3*
(b) base projection	7.4	7.2	7.2	*6.7*
(6) Average yield on industrial bonds, per cent				
(a) case B high	7.7	7.5	7.3	*7.3*
(b) base projection	7.5	7.3	7.2	*7.2*
(7) Increments to total employment, thousands of man-years				
(a) case B high	162	242	227	*1,084*
(b) case B low	125	179	167	*767*
(8) Marginal Percentage increases in real domestic product of industrial sectors				
(a) iron and steel case B high	15.6	11.1	1.1	*3.1*
(b) metal fabricating case B high	6.2	5.9	1.9	*1.2*
(c) manufacturing case B high	3.0	2.4	0.7	*1.0*
case B low	1.6	1.2	.4	*.5*
(d) construction case B high	7.2	7.5	3.4	*2.2*
case B low	6.8	6.8	2.8	*2.0*
(c) transportation case B high	4.6	4.7	2.5	*2.0*
case B low	3.8	3.7	1.9	*1.5*
(f) service case B high	2.0	2.9	2.6	*1.7*
case B low	1.6	2.2	1.9	*1.2*
(g) trade case B high	3.8	3.9	2.1	*1.9*
case B low	2.9	2.8	1.5	*1.3*
(9) Increments to employment by industrial sector, thousands of man-years				
(a) manufacturing case B high	29	37	28	*152*
case B low	16	19	14	*74*
(b) service case B high	27	56	65	*316*
case B low	22	42	47	*227*
(c) construction case B high	25	34	25	*87*
case B low	24	32	23	*81*
(d) transportation case B high	19	28	27	*132*
case B low	16	23	22	*104*

TABLE 4

SUMMARY OF IMPACT OF CASE C (EXTENSIVE DEVELOPMENT)

Items	Years				
	1977	1978	1979	1980	1973–1980
(1) Additional Capital Expenditures Billions of Constant $	1	1.5	1.7	.5	*8*
(2) Rate of growth in real GNP, per cent					
(a) case C high	5.5	5.7	5.1	2.6	*5.5*
(b) case C low	5.7	5.1	4.3	2.8	*5.2*
(c) base projection	5.9	4.4	3.8	4.4	*5.0*
(3) Rate of growth implicit price index of GNE, per cent					
(a) case C high	3.2	4.2	5.4	5.5	*3.9*
(b) case C low	3.2	3.9	4.1	4.0	*3.4*
(c) base projection	2.2	2.9	2.7	2.1	*2.6*
(4) Unemployment rate, per cent					
(a) case C high	3.4	3.1	2.8	3.2	*3.6*
(b) case C low	3.7	3.5	3.5	4.0	*4.0*
(c) base projection	4.8	4.7	5.0	5.0	*4.9*
(5) Rate of increase in money supply in per cent					
(a) case C high	8.4	9.2	9.9	7.9	*8.4*
(b) base projection	7.2	6.7	6.0	6.1	*6.7*
(6) Average yield on industrial bonds, per cent					
(a) case C high	7.7	7.6	7.3	7.0	*7.4*
(b) base projection	7.2	7.1	7.1	6.9	*7.2*
(7) Increments to total employment, thousands of man-years					
(a) case C high	277	333	436	431	*1,965*
(b) case C low	208	246	300	270	*1,404*
(8) Marginal Percentage increases in real domestic product of industrial sectors					
(a) iron and steel case C high	6.6	13.0	13.8	.4	*8.3*
(b) metal fabricating case C high	4.4	5.7	6.5	2.7	*4.1*
(c) manufacturing case C high	1.8	3.2	4.2	2.2	*2.3*
case C low	1.2	1.7	2.3	1.0	*1.3*
(d) construction case C high	6.2	7.9	7.6	2.9	*5.4*
case C low	5.6	7.4	7.5	3.0	*5.1*
(e) transportation case C high	4.1	5.5	7.0	3.7	*4.0*
case C low	3.3	4.2	4.8	1.7	*3.0*
(f) service case C high	3.2	4.0	5.6	5.9	*3.1*
case C low	2.4	2.9	3.7	3.5	*2.2*
(g) trade case C high	3.6	5.3	7.9	5.6	*4.0*
case C low	2.7	3.7	4.8	2.8	*2.7*
(9) Increments to employment by industrial sector, thousands of man-years					
(a) manufacturing case C high	37	47	61	55	*280*
case C low	20	24	31	25	*145*
(b) service case C high	72	85	126	161	*538*
case C low	53	64	87	104	*381*
(c) construction case C high	35	38	36	16	*196*
case C low	33	37	38	22	*196*
(d) transportation case C high	33	40	50	45	*224*
case C low	27	32	37	30	*172*

TABLE 5

SUMMARY OF IMPACT OF CASE D (MAXIMUM DEVELOPMENT)

Items	Years					
	1976	1977	1978	1979	1980	1973–1980
(1) Additional Capital Expenditures Billions of Constant $	2.5	2.5	2.0	2.0	2.0	*13.0*
(2) Rate of growth in real GNP, per cent						
(a) case D high	8.4	6.7	5.0	5.3	6.9	*6.4*
(b) case D low	7.7	6.6	4.9	4.5	5.4	*5.9*
(c) base projection	6.4	5.9	4.4	3.8	4.4	*5.0*
(3) Rate of growth implicit price index of GNE, per cent						
(a) case D high	3.8	5.5	7.0	7.5	8.2	*5.2*
(b) case D low	2.8	4.7	6.0	6.5	6.4	*4.5*
(c) base projection	1.6	2.2	2.9	2.7	2.1	*2.6*
(4) Unemployment rate, per cent						
(a) case D high	2.7	1.9	1.7	1.6	0.9	*2.7*
(b) case D low	3.4	2.6	2.4	2.4	2.1	*3.3*
(c) base projection	5.2	4.8	4.7	5.0	5.0	*4.9*
(5) Rate of increase in money supply in per cent						
(a) case D high	11.4	11.5	11.5	12.5	14.9	*10.7*
(b) base projection	7.2	7.2	6.7	6.0	6.1	*6.7*
(6) Average yield on industrial bonds, per cent						
(a) case D high	7.7	7.6	7.5	7.4	7.3	*7.5*
(b) base projection	7.3	7.2	7.1	7.1	6.9	*7.2*
(7) Increments to total employment, thousands of man-years						
(a) case D high	366	508	611	736	938	*3,421*
(b) case D low	276	378	457	535	632	*2,494*
(8) Marginal Percentage increases in real domestic product of industrial sectors						
(a) iron and steel case D high	21.0	17.9	13.2	13.5	14.0	*13.2*
(b) metal fabricating case D high	11.4	11.3	9.9	9.7	11.0	*7.8*
(c) manufacturing case D high	5.0	5.1	5.2	6.5	8.7	*4.5*
case D low	2.9	3.0	3.7	4.4	5.4	*2.8*
(d) construction case D high	12.4	12.5	10.1	9.0	9.8	*8.2*
case D low	11.9	11.8	9.5	7.9	7.3	*7.5*
(e) transportation case D high	8.4	9.2	9.4	10.5	12.7	*7.3*
case D low	6.6	7.2	7.3	7.6	8.2	*5.5*
(f) service case D high	4.7	6.5	7.9	10.0	13.3	*5.7*
case D low	3.4	4.7	5.8	7.2	8.9	*4.1*
(g) trade case D high	7.8	9.0	10.4	13.3	17.9	*8.2*
case D low	5.4	6.7	7.8	9.5	11.5	*5.8*
(9) Increments to employment by industrial sector, thousands of man-years						
(a) manufacturing case D high	58	74	88	101	132	*499*
case D low	33	41	50	60	75	*288*
(b) service case D high	77	126	171	225	311	*940*
case D low	58	92	126	165	215	*689*
(c) construction case D high	51	58	52	39	30	*268*
case D low	49	58	52	40	26	*262*
(d) transportation case D high	52	59	71	82	97	*393*
case D low	44	47	56	63	69	*307*

TABLE 6

SUMMARY OF IMPACT OF CASE E (DELAYED DEVELOPMENT)

Items	Years 1978	1979	1980	1973–1980
(1) Additional Capital Expenditures Billions of Constant $	1.0	0.8	0.2	*1.2*
(2) Rate of growth in real GNP, per cent				
(a) case E high	5.4	3.2	2.8	*5.0*
(b) case E low	4.8	3.3	3.1	*4.9*
(c) base projection	4.4	3.8	4.4	*5.0*
(3) Rate of growth implicit price index of GNE, per cent				
(a) case E high	3.2	3.6	2.9	*2.9*
(b) case E low	3.2	3.3	2.6	*2.8*
(c) base projection	2.9	2.7	2.1	*2.6*
(4) Unemployment rate, per cent				
(a) case E high	4.1	4.4	5.0	*4.7*
(b) case E low	4.4	4.7	5.2	*4.8*
(c) base projection	4.7	5.0	5.0	*4.9*
(5) Rate of increase in money supply in per cent				
(a) case E high	7.4	6.2	5.4	*6.8*
(b) base projection	6.7	6.0	6.1	*6.7*
(6) Average yield on industrial bonds, per cent				
(a) case E high	7.3	7.2	6.9	*7.3*
(b) base projection	7.1	7.1	6.9	*7.2*
(7) Increments to total employment, thousands of man-years				
(a) case E high	89	109	51	*343*
(b) case E low	57	58	1	*200*
(8) Marginal Percentage increases in real domestic product of industrial sectors				
(a) iron and steel case E high	9.2	5.7	−1.4	*2.0*
(b) metal fabricating case E high	2.8	2.2	−0.5	*0.4*
(c) manufacturing case E high	1.5	0.9	−0.5	*0.3*
case E low	0.4	0.0	−0.9	*0.0*
(d) construction case E high	4.5	3.8	0.8	*1.3*
case E low	4.1	3.3	0.4	*1.1*
(e) transportation case E high	2.2	1.5	−0.6	*0.7*
case E low	1.2	0.8	−1.0	*0.4*
(f) service case E high	1.1	1.4	0.7	*0.5*
case E low	0.8	0.8	0.1	*0.3*
(g) trade case E high	2.0	1.5	−0.2	*0.6*
case E low	1.2	0.7	−0.6	*0.3*
(9) Increments to employment by industrial sector, thousands of man-years				
(a) manufacturing case E high	13	15	4	*34*
case E low	2	1	−8	*−6*
(b) service case E high	18	33	27	*97*
case E low	13	20	12	*62*
(c) construction case E high	16	18	10	*48*
case E low	14	17	9	*43*
(d) transportation case E high	10	12	7	*51*
case E low	8	8	3	*39*

C, the increase in the average unemployment rate with the low level of Canadian content is to 4.0 per cent from 3.6 per cent. On the positive side, the easing of supply pressures in labour markets is most evident during the pipeline construction period when unemployment is below realistic full employment target levels. Again with Case D, the low level of Canadian content results in an average unemployment rate for the period of 3.3 per cent. Even with domestic production capacity being supplemented by additional imports of goods and services, the average rate of unemployment during the last four years of the decade would be less than 2.5 per cent.

Real Output and Employment by Industrial Sector

As discussed above, the macro control solution projects that real gross output will grow at an average annual rate of about 5 per cent. The growth rates exhibited by the major industry groups, however, differ widely as indicated in Table 1. The construction industry output is expected to grow at a higher rate in the 1970's than in the 1960's and this is attributed in large part to assumed additional public construction investment and to the anticipated resource development boom. Similarly, the rates of increase in the outputs of the agricultural, forestry and mining, oil and gas industries are projected to advance at a faster pace in the 1970's than in the 1960's in response to an anticipated buoyant world demand for these primary products. On the other side, industry sectors that are expected to experience slower rates of growth in this decade than in the 1960's are notably manufacturing, transportation, general services and electric, gas and water utilities which, because of strong urban growth, have advanced strongly since World War II. The decline in the expected rate of growth of manufacturing output over 1973-80 from the relatively strong growth environment of the 1960's is largely explained by the absence of such stimuli as special international trading agreements or another large devaluation of the Canadian dollar.

In this setting, the changed energy investment expenditures in Cases A to E involve a direct change in aggregate demand for certain goods and services, particularly in the construction, transportation and manufacturing sectors, which may be met from domestic or external sources. To the extent that any increased demand is met domestically, and again this is determined in the model on the basis of observed historical relationships, the input/output matrix in the model relates how this increased demand for certain goods and services is transmitted to other industry sectors. In Tables 2 to 6, the impact of the various cases on industrial growth is approximated by the marginal percentage changes in real domestic product for select industries. Generally, the differences in average growth rates are directly related to the size of the development programs and are greatest for those industries which supply energy development inputs such as construction, the iron and steel industry and the metal fabricating industry. It is also evident, however, that energy development even in the remote frontier areas would provide an important stimulus to production and employment over the whole economy.

The estimates of the growth and distribution of employment are derived in the model from projections of output, capital stock and anticipated productivity growth. The stimuli to employment of Cases B through E are related directly to their stimuli to industry output demand. The distribution of employment effects

among the various sectors also reflects the wide variation in their capital/labour ratios. Tables 2 to 6 also present the changes to total employment and in employment in certain industrial sectors accompanying Cases A through E. The sectors most greatly affected are the services sector, the manufacturing sector, the transportation sector and the construction industry. It is interesting to note that manufacturing employment in fact increases substantially in all cases, with the exception of the Self-sufficiency Development case, although undoubtedly the relative employment shares of some manufacturing industries would change. If conditions of fuller employment prevail in the economy than suggested by the model, then the requirements of resource development will not be met to the same extent from unemployed resources or the growth in the factors of production. Rather, they will be satisfied by competing factors away from other economic activities or by imports.

The variation of the level of Canadian content in pipeline construction has an important impact on the real output and employment of the different industries. The reduction in the level of Canadian content involves a direct reduction in demand for those industries which supply pipeline inputs as imports replace domestic inputs. Variation in the level of import content appears to be a relatively efficient means of reducing the pressures and disruptions of periodic surges in demand for particular goods and services. In point, with the assumption of the historical level of Canadian content, real domestic product of the iron and steel industry is projected to increase from the control solution projections by 16 per cent in 1975 and 11 per cent in 1976 with Cases B and C and by 13 per cent in 1978 and 14 per cent in 1979 with Case C. To the extent that such levels of demand might be maintained by the resource development sector in the 1980's, the consequent large increases in production capacity in the 1970's may prove viable. With a low level of Canadian content, however, the percentage increases from the macro base for this industry are only marginal. This would mean less pressure on already existing production capacity and result in a less volatile pattern of investment in the industry.

Impact on the Balance of Payments

One of the major difficulties of constructing an econometric model for the Canadian economy is that the economy is open. Canada exports a very large share of its real domestic product and imports a high proportion of its total consumption and as such, the economy is vulnerable to fluctuations in the volatile international financial and commodity markets. At present, there is no econometric model of the Canadian economy which fully determines the external sector. Reservations concerning the balance of payments sector of CANDIDE have been expressed. Consequently, analysis of movements in the exchange rate associated with the different energy case options is somewhat qualitative in approach.

As related, the macro control solution incorporates the Economic Council's Ninth Annual Review assumption of a strong demand from external sources for Canadian goods and services during the 1970's. Exports are assumed to increase at an average rate of real growth approaching 5.75 per cent. Imports which are endogenous to the model are projected to increase at an

average rate of 5.2 per cent per year over the same period. These projections are somewhat below the performance of the 1960's and the explanation is found in the absence of such special factors as the depreciation of the Canadian dollar which improved the competitive position of export and import-competing industries through the 1960's, and the special international trade arrangements which produced further large increases in both exports and imports.

In the absence of the different energy cases, the maximum current account deficit projected for the period is 0.5 per cent of GNP in the years of high demand activity before climbing to a surplus of 0.6 per cent of GNP by 1980. The current account balance tends to decline significantly as the economy approaches full capacity and to increase thereafter as the growth rate moderates. These figures compare to a maximum current account deficit of 4.4 per cent of GNP during the 1950's and a maximum of 2 per cent during the 1960's when foreign economic conditions were favourable.

Capital Account

In this setting, the additions to energy investments in the 1970's associated with the alternative energy cases would be based to a significant degree on increased inflows of foreign direct investment and increased sales of Canadian securities abroad. Moreover, the consequent stimulus to aggregate demand would induce further additions to capital stock in other industry sectors, especially in those industries that supply energy development. This induced investment in turn could require further foreign capital inflows.

Discussions with the industry and the financial community suggest that the percentage of Canadian financing of major pipeline projects in this decade could be as low as 30 per cent as compared with the observed historical average of between 60 and 70 per cent. The use of the lower level of Canadian financing for pipeline development in the study imposes a maximum limit to any upward pressures on the exchange rate required to maintain balance in the external sector.

Noting again the incomplete nature of the balance of payments sector of the model, the simulation work projects the following net inflows of long-term capital over the period 1973-80 with the development cases B to E. With the assumption of low levels of Canadian content and financing for pipelines, the additional foreign direct investment and net sales of Canadian securities abroad required for the period under Case B, is approximately \$3½ billion; and under Case C, the capital inflow is about \$6½ billion. Again, a large proportion of these increments are required during pipeline construction in 1975-76 and in 1978-79. When a lower level of Canadian content is assumed, the foreign financing requirements decrease because there is less induced investment in proportion to the net reduction in stimulus to aggregate demand. For comparison with historical levels of Canadian content and financing for pipeline development, the additional foreign capital inflows required with Cases B and C are \$1½ billion and \$4 billion, respectively.

Under the Maximum Development case, Case D, and with low levels of Canadian content and financing, the increase in foreign capital inflows above the projections in the control solution is estimated at over \$8 billion. This increase tends to be concentrated in the latter part of the decade when a large

number of energy projects come on line. Finally, with the Delayed Development case, relatively small capital inflows are required and these are centred in 1978-79 during the construction of a Mackenzie Valley natural gas pipeline.

Current Account

The resulting surplus on capital account would have to be offset by a deficit on current account if a viable balance of payments is to be maintained. The current account deficit represents the real equivalent of the monetary capital inflows. The adjustment of the current account to accommodate the transfer of real resources implied by the capital inflows centres on price and income effects which are directed at increasing imports relative to exports.

Investment in energy development has historically led to immediate direct increases in the import of machinery and equipment and other construction materials. As the level of Canadian content of pipeline development in the 1970's is expected to be considerably lower than in the past, because of the huge size of the projects, the immediate direct increases in imports should be correspondingly larger. In addition, the consequent increase in real output and income generated by the total additions to investment would lead to increased demand for imports, albeit with some lag.

Depending on the proportion of foreign financing associated with the increased investments, their import content and the state of the economy, the decline in the current account associated with the income effects may or may not be sufficient to fully offset the increased capital inflows. In the resource development boom of the mid-1950's, some change in the terms of trade was required to further stimulate imports and hinder exports. Canada had allowed the exchange rate to respond to market forces at the time and thus, the required price change came about through both increases in the rate of growth of domestic prices and in the appreciation of the Canadian dollar in foreign exchange markets. Under a fixed exchange rate system, any required change in the terms of trade could be effected through increases in domestic prices. To finance additions to foreign exchange reserves and to maintain interest rate differentials between Canada and the United States, the monetary authorities would probably respond by expanding the money supply which would lead to upward pressures on prices.

As real exports of goods and services are assumed to grow at a constant rate over 1970-80 in the control solution, the impacts of the different energy cases on the current account would be determined by their impact on the imports of goods and services and the different assumptions as to levels of petroleum exports. The decline on the current account position with each of the cases should reflect the size of the capital inflows to be accommodated. The largest divergences from the control solution estimates tend to occur during the construction periods of large energy projects which have high import contents. For example in Cases B and C the largest divergences occur during pipeline construction. While the absolute amounts appear high by past standards, when the current account deficit is measured as a proportion of GNE, the maximum with Case B is only 1.5 per cent in 1976 with the low Canadian content assumption. Under Case C, the maximum percentage of GNP for the current account is again 1.5 per cent in

both 1976 and 1979. The deficit with the Maximum Development case is, of course, much greater than with the other cases and by 1980, it reaches a maximum of $5 billion or about 2.25 per cent of GNE.

Impact on the Exchange Rate

Canada's past experiences with large resource development booms would suggest that, with a Maximum Development program at least, the large long-term capital inflows would not be fully offset in the latter part of the decade by the decline in the current account related to the associated income effects. This would require temporary accommodation through short-term capital movements and increases in foreign exchange reserves, appreciation of the exchange rate and/or an increase in the pace of domestic price advance. Analysis of the mid-1950's resource development boom suggests that any appreciation of the exchange rate would not be as marked as in 1956-57 because of the increased ability of the economy to meet its investment requirements and because of the anticipated lower levels of Canadian content in frontier area development than observed historically.

The anticipated impact of the Standard Development case on the domestic macro variables and the projected behaviour of the current account over 1973 to 1980, suggest, however, that no significant change in the terms of trade would be required with Case B. There would probably be some need of short-term accommodation for inflows of foreign exchange during pipeline construction in 1975-76.

The Extensive Development case is somewhere in between as to the required accommodation in the external sector through exchange rate appreciation. Relatively large foreign capital inflows are required from 1975 onwards and the current account position, in the absence of the different energy options, is expected to improve over the latter part of the decade and reach a surplus of over $1 billion by 1980. Although the trade diversification associated with this case and with the Maximum Development case would shift the current account to a deficit position, the large capital inflows should result in basic balance surpluses and lead to upward parity value pressures. This would adversely affect the competitive position of Canadian export and import-competing industries with important implications for the federal regional development programs of income and employment maintenance.

ANNEXE 1

CAPITAL REQUIREMENTS—MACRO BASE PROJECTION

	Utilities Investment (Electric Power, Gas Distribution)		Pipeline Investment (Oil Pipelines and Gas Transmission)		Petroleum Investment[2] (Petroleum and Gas Extraction, Natural Gas Processing and Petroleum Refining)		Total Energy Sector Investment	
	Current Dollars	Constant 1961 Dollars	Current Dollars	Constant 1961 Dollars	Current Dollars	Constant 1961 Dollars	Current Dollars	Constant 1961 Dollars
1971[1]	1,865	1,361	426	288	1,020	743	3,311	2,392
1972	1,837	1,314	328	227	1,005	708	3,170	2,249
1973	2,034	1,445	389	261	1,088	739	3,511	2,445
1974	2,239	1,541	473	311	1,228	808	3,940	2,660
1975	2,370	1,648	519	333	1,383	888	4,272	2,869
1976	2,644	1,830	507	321	1,573	994	4,724	3,144
1977	2,991	2,020	521	323	1,743	1,081	5,255	3,424
1978	3,259	2,151	600	363	1,916	1,154	5,775	3,669
1969	3,485	2,237	650	383	2,042	1,196	6,177	3,816
1980	3,721	2,346	697	400	2,177	1,243	6,595	3,989
Total	26,445	17,893	5,110	3,210	15,175	9,554	46,730	30,657

[1]Actual values for 1971.

[2]Also included are oil marketing outlets and uranium mining.

ANNEXE 2

CONSTANT ADJUSTMENTS TO THE MODEL

(Millions of Dollars—$1961)

	Case A, Self-sufficient Development				Case B, Standard Development				Case C, Extensive Development			
	Utilities	Petroleum	Transportation	Total	Utilities	Petroleum	Transportation	Total	Utilities	Petroleum	Transportation	Total
1973	—	−146	−26	−173	—	—	—	—	—	—	—	—
1974	—	−232	−83	−315	—	242	244	486	—	249	244	493
1975	−42	−167	−44	−254	−42	361	1,206	1,526	−42	380	1,206	1,545
1976	−104	−299	−38	−440	−104	346	1,161	1,402	−104	408	1,191	1,495
1977	−131	−417	−62	−609	−131	168	292	330	−131	364	599	832
1978	−155	−761	−108	−1,023	−155	−138	−63	−355	−155	345	1,250	1,440
1979	−71	−776	−134	−981	−70	−204	−90	−365	−70	492	1,187	1,608
1980	−29	−585	−158	−772	−29	−392	−115	−536	−29	−48	395	317
Total	−531	−3,382	−652	−4,566	−531	383	2,635	2,487	−531	2,189	6,071	7,729

	Case D, Maximum Development				Case E, Delayed Development			
	Utilities	Petroleum	Transportation	Total	Utilities	Petroleum	Transportation	Total
1973	—	—	—	—	—	—	—	—
1974	—	249	244	493	—	−57	−83	−140
1975	33	634	1,303	1,970	−42	24	−44	−62
1976	44	814	1,599	2,457	−104	−92	−37	−233
1977	49	693	1,579	2,321	−131	94	170	133
1978	54	814	1,101	1,969	−155	29	1,081	955
1979	132	562	1,045	1,739	−70	4	904	837
1980	171	1,424	938	2,533	−29	−155	340	156
Total	482	5,189	7,808	13,479	−531	−153	2,330	1,646

ANNEXE 3

ARCTIC TRANSPORTATION COSTS ADJUSTMENT[1]

(Millions of Dollars, $ 1961)

	Case B, Standard Development			Case C, Extensive Development		
	Petroleum Construction Investment Increments	Pipeline Construction Investment Increments	Adjustments for Arctic Transportation Costs	Petroleum Construction Investment Increments	Pipeline Construction Investment Increments	Adjustments for Arctic Transportation Costs
1974	232	207	63	239	208	43
1975	341	1,004	162	361	1,004	166
1976	331	970	157	394	1,000	173
1977	183	266	60	337	538	120
1978	−85	−35	—	349	1,128	176
1979	−135	−58	—	496	1,074	197
1980	−294	−76	—	12	375	—

	Case D, Maximum Development			Case E, Delayed Development		
	Petroleum Construction Investment Increments	Pipeline Construction Investment Increments	Adjustments for Arctic Transportation Costs	Petroleum Construction Investment Increments	Pipeline Construction Investment Increments	Adjustments for Arctic Transportation Costs
1974	239	208	64	−34	−69	—
1975	568	1,082	211	44	−34	—
1976	735	1,355	268	−54	−18	—
1977	649	1,400	257	122	161	38
1978	557	997	200	62	905	102
1979	562	928	144	48	771	86
1980	606	818	89	−87	314	16

[1]No adjustments were made in Case A, the self-sufficient resource development program since no expenditures are anticipated to be made for the development of Arctic reserves or pipeline transportation networks.

Annexe 4

GEOLOGICAL AND GEOPHYSICAL EXPENDITURES

(Millions of Dollars, $ 1961)

	Case A Self-sufficient Development	Case B Standard Development	Case C Extensive Development	Case D Maximum Development	Case E Delayed Development	Basic Projection
1973..........	58	170	170	170	163	145
1974..........	62	184	184	184	171	155
1975..........	58	173	192	192	185	165
1976..........	56	169	201	201	201	180
1977..........	55	166	209	215	215	190
1978..........	60	179	215	239	197	205
1979..........	64	192	221	262	192	220
1980..........	68	204	227	284	187	235
Total..........	481	1,437	1,619	1,747	1,511	1,495

Annexe 5

ALTERNATIVE EXPORT PATTERNS AND INVESTMENT CASES

	Scenario 1		*Scenario 2*		*Scenario 3*	
	(Self-sufficient Development, Case A)		(Standard Development, Case B) (Extensive Development, Case C) (Maximum Development, Case D)		(Delayed Development, Case E)	
	Oil and Products Exports 10^{12} Btu*	Natural Gas Exports 10^{12} Btu	Oil and Products Exports 10^{12} Btu	Natural Gas Exports 10^{12} Btu	Oil and Products Exports 10^{12} Btu	Natural Gas Exports 10^{12} Btu
1973..............	1,600	900	2,000	950	2,000	950
1974..............	1,700	900	2,200	950	2,200	950
1975..............	1,800	900	2,400	1,000	2,400	1,000
1976..............	1,800	900	2,600	1,000	2,600	1,000
1977..............	1,700	900	2,800	1,000	2,800	1,000
1978..............	1,600	900	2,750	1,300	2,750	1,050
1979..............	1,500	900	2,700	1,450	2,700	1,100
1980..............	1,400	900	2,650	1,500	2,650	1,150

* In Case A, exports of crude oil and products equals imports.

ANNEXE 6

INCREASED IMPORTS FOR LOW CANADIAN CONTENT

(Millions of Current $)

	Case B, Standard Development			Case C, Extensive Development		
	Investment in Northern and Offshore Pipeline Systems	Import Adjustments for Pipeline Construction	Total Imports of Goods and Services for Pipeline Construction	Investment in Northern and Offshore Pipeline Systems	Import Adjustments for Pipeline Construction	Total Imports of Goods and Services for Pipeline Construction
1974	500	193	260	500	194	260
1975	2,000	772	1,033	2,000	772	1,033
1976	2,000	772	1,033	2,000	772	1,033
1977	600	233	311	1,100	417	561
1978	100	39	52	2,300	871	1,171
1979	100	40	53	2,300	872	1,172
1980	100	39	60	1,000	379	509

	Case D, Maximum Development			Case E, Delayed Development		
	Investment in Northern and Offshore Pipeline Systems	Import Adjustments for Pipeline Construction	Total Imports of Goods and Services for Pipeline Construction	Investment in Northern and Offshore Pipeline Systems	Import Adjustments for Pipeline Construction	Total Imports of Goods and Services for Pipeline Construction
1974	500	194	260	—	—	—
1975	2,150	813	1,094	50	18	23
1976	2,650	1,001	1,347	50	19	24
1977	2,700	1,022	1,373	500	193	255
1978	2,050	776	1,042	2,000	758	1,006
1979	2,050	777	1,043	1,800	683	907
1980	1,950	739	993	900	341	452

NOTES TO ANNEXE 1

METHODOLOGY USED TO DERIVE ENERGY SECTOR SPENDING IMPLICIT IN MACRO BASE SOLUTION (SEPTMODEL CONTROL)

The CANDIDE model contains detail for investment expenditures by 11 major industrial sectors. However, in some cases investment spending by an energy industry is grouped within a larger industrial sector and must be disaggregated. As an interim measure to determine the energy sector spending implicit in the September model control solution several methods were tested. The first and most obvious approach was to assume that the historical proportions would persist. For example, one might assume that the petroleum industry's investment as a proportion of the mining, quarrying and oil wells total would remain constant in the future. This was rejected for the petroleum sector. The approach used was to ascertain the proportion by regression analysis, using such explanatory variables as petroleum industry Real Domestic Product.

For the utilities and refining sectors, the CANDIDE mnemonics UTICOK, UTIMEK, M18IMK and M18ICK were simply multiplied by their respective deflators to arrive at current dollar estimates. The regressions used to ascertain the proportion of petroleum sector spending in MIICOK and MIIMEK, and the pipeline expenditures in T8ICOK and T8IMEK were as follows (CANDIDE mnemonics and others as noted below)

$$
\begin{aligned}
\text{PGPCON} &= B_0 + B_1 \ * \ \text{MIO1Y} \\
\text{PGPME} &= B_2 + B_3 \ * \ \text{MIO1Y} + B_4 \ * \ \text{TIME} \\
(\text{IOPKB} + \text{IOPKE}) &= B_5 + B_6 \ * \ \text{T8ICOK} \\
\text{IOPKM} &= B_7 + B_8 \ * \ \text{T8IMEK} + B_9 \ * \ \text{TIME}
\end{aligned}
$$

where PGPCON, PGPME

Petroleum Extraction and Natural Gas Processing Construction and Machinery and Equipment Expenditures, 1961 dollars (deflators MIICOP, MIIMEP)

IOPKB, IOPKE, IOPKM

Pipelines, Investment Spending, Building Construction, Engineering Structures and Machinery respectively, 1961 dollars (available on CANDIDE auxiliary data tape)

MIO1Y

Real Domestic Product, Petroleum and Gas Wells Industry

T8ICOK, T8IMEK

Other Transportation, Construction and Machinery and Equipment Expenditures, 1961 dollars

MIICOK, MIIMEK

Mining, Quarrying and Oil Wells, Construction and Machinery and Equipment Expenditures, 1961 dollars

UTICOK, UTIMEK

Utilities Industry (defined as Electric Power and Gas Distribution) Construction and Machinery and Equipment Expenditures, 1961 dollars (deflators UTICOP, UTIMEP)

M18ICK, M18IMK

Petroleum and Coal Products Industry, Construction and Machinery and Equipment Expenditures, 1961 dollars (deflators M18ICP, M18IMP)

To determine the expenditures implicit in the model for oil marketing outlets, coal and uranium mining simple extrapolations of historical percentages were made.

NOTE TO ANNEXE 2

CONSTANT ADJUSTMENTS MADE TO CANDIDE INVESTMENT EQUATIONS

The constant adjustments are shown in Annexe 2 for Cases A through E for the utilities, petroleum and pipeline transportation industries. These adjustments were divided between the two categories of investment in CANDIDE (i.e. non-residential construction and investment in machinery and equipment) on the basis of historical time series. Geological and geophysical expenditures above those in the base projections are also included—see note to Annexe 4.

Note to Annexe 3

The input/output model in CANDIDE breaks the total non-residential construction expenditures made for investment purposes by the petroleum and pipeline industries into seven different general types of construction "commodities". While there are already certain transportation margins implicit in the production of these commodities, an upward adjustment was made on the assumption that 20 per cent of the total development costs for Arctic reserves are direct purchases of transportation services. An upward adjustment was also made for the transportation component of the capital expenditures on pipeline construction. After this revision, the proportion of total pipeline construction cost required for transportation services was 13 per cent. This revision was based on input data supplied for an internal study. Annexe 3 shows the investment increments and the increased transportation expenditures (or conversely the reduced expenditures on engineering structures, buildings and conventional structures) for the petroleum and transportation industries assumed in each case.

The first two columns under each case heading show the constant adjustments made for construction expenditures and the increase made to TRSVCR, (transportation commodity requirements).

Note to Annexe 4

GEOLOGICAL AND GEOPHYSICAL EXPENDITURES: TREATMENT IN CANDIDE FOR INVESTMENT IMPACT STUDY

Geological and geophysical expenditures in the input/output model are treated as an operational input linear to output. Therefore, the gross output of the petroleum industry in the control solution is the determinant of the expenditures made for geological and geophysical activities. Multiplication of the September Model forecasted gross output (GAPEIO) by the appropriate coefficients yields the figure shown as the basic projection. The value of geological and geophysical expenditures required in each of the five cases is also shown, and it is the difference of each from the basic projection that was added to the constant adjustments discussed in Annexe 2.

Note to Annexe 6

INCREASED IMPORTS FOR LOW CANADIAN CONTENT

Annexe 6 shows for each case the increased imports assumed to be required with low levels of Canadian content. Under each case the investment expenditures for northern and offshore pipeline systems as well as the total import of goods and services for pipeline construction are shown. This total includes the adjustments as well as the direct imports caused by changes to aggregate investment in machinery and equipment (IME). The constant adjustments were made to imports of processed goods (PROCMK) and other service payments abroad (OTSUMC), with modifications to the commodity requirements generated in the input/output final demand matrix by PROCMK.

APPENDIX B

PART 2. FOREIGN OWNERSHIP AND CONTROL IN THE ENERGY INDUSTRIES

Chapter 1

THE EXTENT OF FOREIGN OWNERSHIP AND CONTROL

DEFINITION

Ownership. To know that 99.9% of the votes of Canadian companies are Canadian-owned could be quite misleading if the size distribution of companies is such that 10% of the corporations account for 90% of the business carried on. For this reason a series of financial measures are related to ownership of voting shares. Computation of ownership is often complex: for a simple example, if Canadian Company A is 60% owned by Canadian Company B which is 60% owned by foreign Company C the percentage of foreign ownership recorded would be 36 (60% of 60%).[1]

The problem of nominee ownership complicates the process at the best; at the worst it presents an impassable wall. To the ownership analyst the nominee-owned (brokerage house, trust account, etc.) share is the equivalent of a bearer bond: nameless, yet owned by someone. Generally the problem is resolved herein, and by CALURA, by assuming the shares to be Canadian unless proven otherwise, but this obviously understates the percentage of non-resident ownership.

For these reasons, ownership of voting rights is related to a series of key financial accounts such as Total Assets, Total Equity, Total Sales, Book Profit, and the like which are useful measures when faced with a "going concern". Many analysts tend to prefer one or other of these and, for example, Sales are, for some purposes, more revealing than the most common yardstick: Assets. But no one yardstick is useful for all cases.

Control. The ultimate purpose of all these calculations is to determine control. CALURA considers a company to be foreign controlled if 50% or more of the voting stock is known to be held outside Canada, or by one or more Canadian companies which are, in turn, foreign controlled; IIP (International Investment Position, compiled by the Balance of Payments Division of Statistics Canada) records an enterprise as foreign controlled if 50% or more of its voting stock is held *in one country* outside Canada; while I.T. & C. regards a company as foreign controlled if 50% of its voting stock is owned by one foreign parent.

[1] For the purpose of this study, "foreign" is generally treated as synonymous with "non-resident". The term relates to ultimate ownership or ultimate control and is calculated from the number of votes to which shareholders are entitled, some shares being non-voting while others entitle their owners to multiple votes. The source data is the Schedule A form of the Corporations and Labour Unions Returns Act Annual Report, and the methodology conforms to that used by CALURA.

All of these statistical definitions have some merit; as a statistical definition the CALURA yardstick seems to be preferable to the other two, and has therefore been used by us in preparing the following tables, but all such statistical definitions are prone to the same practical error: a company is controlled by an individual, company or group which can obtain the majority of the votes cast. When shares are widely distributed, as those of listed corporations tend to be, it is often quite unnecessary for those who wish to control the company to acquire 50% plus one of the voting shares. Companies are often effectively controlled by persons, groups or other companies which own less than 10% of the voting shares.

Under these circumstances we have had to settle for a statistical definition for the purposes of this study, but we should be well aware of the faults inherent in this type of measuring device.

Caveat. Although it is possible to control a company while owning less than 50% plus one of the voting shares, it is also possible to influence the decisions of the management by providing all, or even the bulk, of the long-range bond financing or by other contractual relationships. This, of course, would not be indicated by the share-ownership data. In addition to this possibility, however, is the apparent advent of effective monopsonic elements into the western metallurgical component of the Canadian coal industry. In view of the Japanese government/industry relationship it is apparent that this centralized (if not single) buyer can have a powerful decision-making effect upon the industry.

The Electrical Generation Industry

Foreign ownership measured by assets, has declined from an estimated 8.4% in 1960 to a low of 2.2% in 1966, and has risen steadily since that time to 3.5% in 1970.

The overall downward trend is principally due to provincial takeovers. Indeed, the most significant single characteristic of the Canadian electrical generation industry is the dominant position of the public authority owned utilities. The structure of the industry is such that this group accounts for 88% of the total industry assets.

The table indicates that non-residents' share of profits is several times higher than their share of assets. This is because these utilities behave like non-profit making institutions. The low level of profits of the provincial utilities is not due to relative inefficiency but to socially oriented policies.

The Petroleum Industry

The degree of foreign ownership of the Canadian petroleum industry was virtually unchanged during the 1960's in terms of assets but foreign control of sales and profits increased substantially. A small group of foreign-controlled companies now has virtually complete control of petroleum marketing in Canada. This has important implications with regard to market shares and pricing policies.

Oil Pipeline Industry

Foreign ownership of the oil pipeline industry has increased from 34.5% in 1960 to 39.2% in 1970, but the amount of industry assets controlled by foreigners has grown from 13% in 1960 to 32.2% in 1970.

It should be borne in mind throughout all discussions of control that we are referring specifically to statistical control: the country in which residents own a sufficient number of shares to control 50% plus 1 of the votes, and not to effective control.

Gas Pipeline Industry

Foreign ownership of the gas pipeline industry has declined from 27.9% in 1960 to 25.0% in 1970, but the proportion of profits earned by companies controlled by non-residents has increased from 21.1% to 26.3%. These developments are largely due to a number of minor portfolio changes.

Both the oil and the gas pipeline industries are thus essentially Canadian-owned and Canadian-controlled, but since their additions to handling capacity are governed by the National Energy Board the performance of these industries has a degree of Canadian government-influence rather than being solely ownership-influenced.

Natural Gas Distribution Industry

Foreign ownership and control have both declined in the natural gas distribution industry in the 1960-1970 period; the anomalous bump in 1968-1969 being brought about by the shift from below-to-above-to-below the 50% mark in one or two companies.

Coal Mining Industry

Foreign ownership and control of our coal industry fluctuated around 50% (ownership) and 40% (control) from 1960 to 1967. In 1968 two significant changes occurred: the Dominion Coal mines were taken over by the Cape Breton Development Corporation (Devco) in the east; and in the west, Kaiser began large capital investments aimed at the development of a major reserve of metallurgical coal for shipment to Japan. The result of the latter was a sharp rise in the foreign ownership and control levels.

The structure and thrust of the Canadian coal mining industry is now undergoing a metamorphosis. The major growth of the industry in future years, however, will be western and, as new western metallurgical mines are brought into production, the foreign ownership and control will tend to grow.

Control, however, is not solely a matter of owning the voting shares. The provision of long-term debt capital and the undertaking of long-term supply contracts can also give a degree of control over the operations of a business. The comparatively major growth expected is all based upon exports, and the exports are virtually all to Japan. Even though there may be a number of buyers, the characteristic government-industry relationship in Japan is such that we may also be watching the emergence of an effectual monopsony during the coming decade.

Uranium Mining Industry

Foreign ownership and control of this industry has declined substantially during the sixties but, because of the development of the Gulf operation at Rabbit Lake, it is now about to increase. By 1975 the commencement of production of this new deposit will probably lift the foreign ownership and control figures back to the vicinity of 40 per cent.

FOREIGN OWNERSHIP AND CONTROL, ALL ENERGY INDUSTRIES, 1960–1970

	Assets			Equity			Sales			Book Profit		
Year	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC
1960........	13,289	35.3	35.2	4,812	45.5	48.8	4,076	52.5	60.0	280	44.5	44.9
1961........	14,309	34.6	36.2	5,576	43.2	46.9	4,368	53.3	61.8	321	49.1	50.4
1962........	15,350	34.2	35.4	6,211	45.2	48.6	4,743	53.8	61.9	388	52.9	53.6
1963........	17,094	33.3	36.4	6,256	48.6	56.4	5,209	52.3	63.2	432	53.6	59.2
1964........	18,106	33.5	35.6	6,696	49.8	55.8	5,773	54.7	64.3	486	54.2	58.6
1965........	20,001	33.5	36.9	7,718	51.4	57.7	6,200	53.7	63.7	571	52.2	56.6
1966........	21,900	33.7	36.7	8,596	51.0	56.9	6,661	53.8	63.2	657	56.0	61.4
1967........	24,154	33.4	36.6	9,466	50.5	56.2	7,148	52.9	62.7	730	54.7	60.9
1968........	26,772	34.0	39.2	10,198	50.6	59.3	7,680	53.2	63.4	793	54.7	63.4
1969........	29,293	33.4	37.9	11,221	50.7	58.6	8,118	53.1	62.6	864	57.1	64.0
1970........	31,396	31.7	35.1	12,083	49.1	54.9	9,181	52.0	62.4	935	53.3	60.5

FOREIGN OWNERSHIP AND CONTROL, ELECTRICAL GENERATION INDUSTRY, 1960–1970

Year	Assets			Equity			Sales			Book Profit		
	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC
1960[1]........	6,623	8.4	2.0	1,685	12.0	4.0	950	10.2	2.2	95	18.3	4.7
1961[1]........	6,976	5.1	2.0	2,138	8.8	3.3	951	6.8	2.2	89	16.7	4.7
1962........	7,587	5.2	2.0	2,299	9.3	3.3	1,023	6.7	2.1	94	15.6	4.3
1963........	8,164	2.7	2.0	1,821	6.0	3.9	1,092	2.9	2.3	76	10.2	6.4
1964........	8,749	2.5	1.9	1,924	5.8	3.7	1,222	2.8	2.4	98	10.1	5.2
1965........	9,758	2.5	1.7	2,153	6.4	3.4	1,333	2.7	2.3	118	8.3	4.3
1966........	10,633	2.2	1.5	2,345	6.0	3.1	1,431	2.6	2.3	116	8.9	4.7
1967........	11,944	2.7	0.9	2,735	8.3	2.4	1,582	2.2	1.7	143	7.5	2.6
1968........	13,160	3.3	4.0	2,997	9.9	13.4	1,766	2.4	2.5	155	10.1	13.4
1969........	14,581	3.4	3.7	3,339	9.2	12.8	1,944	2.3	2.3	175	8.8	10.9
1970........	15,966	3.5	1.0	3,614	8.1	2.1	2,200	2.2	1.8	182	7.8	4.8

[1]For 1961 and 1962, pre-CALURA years, dollar figures are actual but ownership and control percentages are estimates.

FOREIGN OWNERSHIP AND CONTROL, ELECTRICAL GENERATION INDUSTRY, NON-PROVINCIALLY-OWNED GROUP, 1960–1970

	Assets			Equity			Sales			Book Profit		
Year	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC
1960[1]........	535	30.0	24.8	234	31.8	28.8	104	26.4	20.1	19	31.5	23.3
1961[1]........	612	31.6	23.8	292	33.7	24.3	111	25.8	19.2	24	32.4	17.8
1962........	649	31.6	24.0	304	34.3	25.1	119	25.2	18.4	27	31.7	15.3
1963........	711	31.7	23.9	330	33.4	21.6	127	25.6	20.3	25	31.8	20.0
1964........	752	29.6	22.4	354	31.6	20.4	140	25.1	20.5	33	30.3	15.8
1965........	859	28.8	20.1	432	32.2	16.9	152	23.9	20.7	34	28.5	15.0
1966........	861	28.2	19.8	458	30.4	16.3	156	24.1	21.7	36	28.7	15.0
1967........	1,132	29.2	10.3	666	34.3	10.1	174	20.9	16.0	39	27.3	9.8
1968........	1,331	32.9	39.8	759	39.2	53.1	193	22.7	23.2	45	34.6	46.2
1969........	1,570	31.9	35.0	806	38.1	53.3	205	22.4	22.4	47	32.8	40.7
1970........	1,870	30.5	9.1	848	34.8	9.0	226	22.2	18.4	48	29.7	18.5

[1]For 1961 and 1962, pre-CALURA years, dollar figures are actual but ownership and control percentages are estimates.

FOREIGN OWNERSHIP AND CONTROL, PETROLEUM INDUSTRY, 1960–1970

Year	Assets			Equity			Sales			Book Profit		
	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC
1960[1]........	4,571	77.3	89.8	2,412	74.3	89.2	2,543	72.6	89.8	110	70.6	88.6
1961[1]........	5,099	77.9	90.3	2,686	75.1	89.8	2,799	73.2	90.1	150	73.7	88.4
1962........	5,381	78.0	90.2	3,094	76.3	90.6	3,074	74.1	90.4	201	78.5	91.6
1963........	6,315	76.6	92.3	3,622	74.8	93.0	3,432	72.8	92.4	247	75.6	92.4
1964........	6,586	79.2	91.8	3,834	78.1	93.0	3,861	76.2	93.3	284	78.6	92.1
1965........	7,279	78.7	91.4	4,502	79.2	92.9	4,049	76.6	93.3	316	78.2	91.5
1966........	8,062	79.0	90.3	5,033	78.8	91.6	4,351	76.9	92.5	408	79.1	92.3
1967........	8,780	79.2	92.0	5,389	79.1	93.2	4,603	76.7	93.2	441	79.3	94.2
1968........	9,762	79.0	92.4	5,715	78.6	92.6	4,892	77.7	93.7	483	78.2	92.9
1969........	10,419	79.1	91.7	6,304	79.2	91.8	5,038	79.6	95.3	530	83.0	95.6
1970........	10,725	76.8	91.3	6,785	77.1	91.4	5,620	78.5	95.9	563	77.8	92.9

[1]For 1961 and 1962, pre-CALURA years, dollar figures are actual but ownership and control percentages are estimated.

FOREIGN OWNERSHIP AND CONTROL, PETROLEUM TRANSPORTATION INDUSTRY, 1960–1970

Year	Assets			Equity			Sales			Book Profit		
	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC
1960[1]........	1,688	26.0	17.3	515	25.4	15.5	366	24.7	14.8	43	27.9	15.2
1961[1]........	1,838	25.1	16.8	548	24.2	15.1	388	24.2	14.2	48	26.6	15.8
1962........	1,990	25.7	15.7	596	25.1	14.0	463	24.8	12.4	64	28.0	11.1
1963........	2,229	22.0	4.5	627	23.0	5.0	528	22.7	4.8	79	27.2	10.3
1964........	2,367	21.1	4.2	694	21.7	4.9	579	21.4	4.6	94	25.4	8.2
1965........	2,564	23.2	17.0	809	22.6	15.3	656	21.7	13.6	114	27.3	14.6
1966........	2,810	22.8	16.6	960	21.1	13.8	737	21.0	13.4	115	23.9	10.4
1967........	3,044	21.8	17.3	1,073	19.5	13.4	820	20.2	14.1	126	24.0	14.1
1968........	3,436	22.8	23.2	1,202	20.8	21.0	902	21.3	21.1	138	24.6	20.5
1969........	3,770	22.1	20.7	1,244	20.2	17.3	1,013	21.1	18.5	141	23.0	17.2
1970........	4,108	21.8	18.7	1,346	20.1	15.4	1,225	21.9	19.5	176	25.5	19.4

[1]For 1961 and 1962, pre-CALURA years, dollar figures are actual but ownership and control percentages are estimated.

FOREIGN OWNERSHIP AND CONTROL, OIL PIPELINE INDUSTRY, 1960–1970

	Assets			Equity			Sales			Book Profit		
Year	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC
1960[1]........	450	34.5	13.0	133	38.2	18.3	89	35.4	18.7	26	35.0	10.7
1961[1]........	457	34.6	14.6	132	37.9	19.7	93	34.9	18.2	27	36.3	19.0
1962........	493	33.9	13.0	144	36.7	18.0	107	34.9	17.0	32	36.0	14.3
1963........	494	33.4	13.8	146	35.7	19.0	113	35.4	18.0	36	39.0	20.9
1964........	486	31.8	13.4	152	34.4	18.8	121	33.7	17.6	42	35.9	16.3
1965........	516	32.3	16.4	167	33.1	18.7	128	32.5	16.9	51	35.2	14.0
1966........	584	35.4	20.1	180	33.6	19.8	141	32.4	17.2	48	33.5	13.9
1967........	602	35.4	23.8	195	32.5	21.2	156	32.6	20.6	54	33.0	18.0
1968........	639	37.4	27.0	213	33.1	22.6	164	33.7	21.6	51	33.4	18.2
1969........	647	37.7	28.0	220	31.3	21.1	183	33.0	22.1	50	31.8	18.3
1970........	715	39.2	32.2	253	33.7	29.0	203	35.3	25.9	73	38.2	30.0

[1]For 1961 and 1962, pre-CALURA years, dollar figures are actual but ownership and control percentages are estimated.

FOREIGN OWNERSHIP AND CONTROL, GAS PIPELINE INDUSTRY, 1960–1970

	Assets			Equity			Sales			Book Profit		
Year	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC
1960[1]........	662	27.9	34.1	146	29.0	37.1	129	25.2	27.5	9	19.0	21.1
1961[1]........	769	25.9	30.3	162	27.0	34.5	133	24.8	27.0	8	9.4	25.0
1962........	775	26.3	30.9	165	26.9	34.4	151	23.4	24.5	13	18.0	17.2
1963........	936	20.2	2.5	182	21.6	1.4	181	21.0	1.2	19	15.2	1.8
1964........	1,006	21.5	2.3	225	22.8	1.3	200	22.0	1.0	23	17.5	1.5
1965........	1,108	27.6	30.8	253	29.3	35.4	227	26.5	27.8	31	26.3	28.6
1966........	1,144	26.3	29.4	328	25.9	28.7	251	25.8	28.0	28	20.7	16.3
1967........	1,209	25.8	30.6	340	25.2	29.2	275	24.6	28.5	30	23.8	25.2
1968........	1,396	26.8	31.8	438	24.4	27.2	316	25.1	28.5	38	26.2	29.8
1969........	1,557	26.7	30.6	454	24.6	26.6	369	25.2	27.5	36	24.7	25.6
1970........	1,774	25.0	29.5	472	24.1	27.7	510	27.2	35.3	44	23.8	26.3

[1]For 1961 and 1962, pre-CALURA years, dollar figures are actual but ownership and control percentages are estimated.

FOREIGN OWNERSHIP AND CONTROL, NATURAL GAS DISTRIBUTION INDUSTRY, 1960–1970

	Assets			Equity			Sales			Book Profit		
Year	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC
1960[1]........	576	17.1	1.5	236	15.8	0.4	147	17.8	1.4	800	15.2	3.5
1961[1]........	613	16.9	1.4	255	15.2	0.4	163	17.6	1.5	13	16.3	2.7
1962........	722	19.4	1.3	287	18.3	0.3	206	20.5	1.3	20	21.6	1.8
1963........	800	17.2	1.2	299	17.6	0.3	234	17.9	1.2	24	19.4	1.6
1964........	875	14.5	1.2	318	14.9	0.8	257	15.1	1.4	29	16.6	1.8
1965........	940	13.1	1.2	389	13.7	0.7	301	13.5	1.3	32	15.8	1.8
1966........	1,082	12.4	1.2	451	12.7	0.6	346	12.8	1.2	38	14.3	1.5
1967........	1,233	11.3	1.1	538	11.1	0.6	389	11.9	1.4	43	12.9	1.4
1968........	1,401	12.1	13.0	551	13.1	15.5	423	13.8	15.3	49	14.2	15.8
1969........	1,566	11.2	7.9	570	12.5	8.4	461	13.0	9.9	55	13.6	10.7
1970........	1,619	10.7	1.0	621	11.6	0.6	512	11.3	1.4	59	11.2	1.3

[1]For 1961 and 1962, pre-CALURA years, dollar figures are actual but ownership and control percentages are estimates.

FOREIGN OWNERSHIP AND CONTROL, COAL MINING INDUSTRY, 1960–1970

	Assets			Equity			Sales			Book Profit		
Year	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC
1960[1]........	Confidential	50.2	37.4	Confidential	52.2	45.0	Confidential	46.5	22.1	Confidential	40.6	42.0
1961[1]........	„	50.5	38.2	„	51.3	44.3	„	47.4	24.8	„	45.1	51.2
1962........	„	50.2	38.2	„	50.8	43.9	„	47.7	25.4	„	50.9	58.7
1963........	„	53.9	41.8	„	51.8	45.3	„	49.3	25.0	„	49.6	40.1
1964........	„	52.1	42.8	„	52.9	46.9	„	48.6	28.5	„	78.8	124.8[2]
1965........	„	49.8	42.5	„	49.6	45.1	„	48.9	33.2	„	64.9	115.8[2]
1966........	„	46.8	40.8	„	48.0	45.1	„	47.7	37.9	„	54.9	70.8
1967........	„	49.6	43.9	„	50.5	45.1	„	49.2	38.0	„	38.4	29.0
1968........	„	66.9	65.6	„	67.4	66.2	„	54.4	38.1	„	32.6	21.1
1969........	„	62.2	76.0	„	64.6	79.0	„	31.5	39.0	„	114.0[2]	177.7[2]
1970........	„	60.3	73.2	„	56.7	66.7	„	33.1	42.7	„	73.7	128.1[2]

[1]For 1961 and 1962, pre-CALURA years, ownership and control percentages are estimates.
[2]These apparently strange percentages are due to (subsidized) losses in other companies.

FOREIGN OWNERSHIP AND CONTROL, URANIUM MINING INDUSTRY, 1960–1970

Year	Assets			Equity			Sales			Book Profit		
	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC	($000,000)	% NRO	% NRC
1960[1]........	Confidential	38.7	34.9	Confidential	29.3	21.8	Confidential	49.0	46.7	Confidential	55.4	54.8
1961[1]........	„	35.4	30.8	„	31.0	21.6	„	53.7	50.5	„	57.9	51.6
1962........	„	32.8	27.5	„	32.6	22.8	„	51.3	47.1	„	50.6	42.8
1963........	„	33.3	32.3	„	30.8	21.6	„	49.4	53.4	„	52.1	49.8
1964........	„	29.2	29.6	„	28.5	22.5	„	51.2	70.4	„	61.5	96.0
1965........	„	27.5	29.4	„	26.8	23.9	„	23.9	30.1	„	42.1	45.7
1966........	„	25.0	28.1	„	24.4	24.9	„	24.6	32.4	„	40.8	49.2
1967........	„	28.0	26.0	„	28.2	25.5	„	26.2	30.9	„	42.5	41.6
1968........	„	26.9	23.1	„	28.6	27.3	„	31.2	35.7	„	38.1	30.1
1969........	„	24.4	21.0	„	27.3	26.4	„	32.7	38.0	„	36.9	24.5
1970........	„	24.3	22.5	„	26.3	26.9	„	31.8	36.4	„	29.4	30.7

[1]For 1961 and 1962, pre-CALURA years, ownership and control percentages are estimates.

Chapter 2

FOREIGN TAKEOVERS, 1963-70

The following pages list the takeover by foreign-controlled companies, of companies which were previously Canadian-controlled.

Beginning with 1969, the data are set out to permit examination of four combinations of takeovers:

Foreign takeovers of Canadian-controlled companies;
Foreign takeovers of foreign-controlled companies;
Canadian takeovers of Canadian-controlled companies; and
Canadian takeovers of foreign-controlled companies.

The reader should note that this is not an official list and therefore is not exhaustive for all years—particularly those preceding 1969.

Foreign Takeovers, 1963-1968

Foreign Controlled Acquiring Company	Canadian Controlled Company Acquired
1963	
British Petroleum Co. Ltd.	Paris Petroleum Ltd.
Anlage Bank Zurich	Charter Oil Co. Ltd.
Pacific Petroleums Ltd. (Phillips Petroleum U.S.)	Bailey Selburn Oil & Gas Ltd.
Rio Algom Mines Limited (Rio Tinto Co. Ltd.)	Atlas Steels Ltd.
Western Decalta Petroleum Ltd.	New Brunswick Oilfields Ltd.
Western Decalta Petroleums Ltd.	South Brazeau Petroleums Ltd.
1964	
British Petroleum Co. Ltd.	Gobles Gas & Oil Ltd.
British Petroleum Co. Ltd.	Tidewater Canadian Oil Ltd.
B.P. Canada Ltd.	City Service Oil Co. Ltd.
Great Plains Development Co. of Canada Ltd.	Canada Oil Lands
Husky Oil Canada	Sarcee Petroleums
Imperial Oil Ltd. (Standard Oil Co. (N.J.))	Building Products Ltd.
Occidental Petroleum Corp.	Jefferson Lake Petro-Chemicals of Canada Ltd.
Sage Oil Company Ltd.	Marjack Oils Ltd.
Société National des Pétroles d'Aquitaine	Banff Oil Ltd.

Foreign Controlled Acquiring Company	Canadian Controlled Company Acquired
1965	
Great Plains Development Co. of Canada	Westburne Oil Development Ltd.
Richfield Oil Corp.	Candel International Ltd.
Standard Oil Co.	Canadian Delhi Oil Ltd.
Union Oil Company of Canada	Pure Oil Ltd.
1966	
Baker Oil Tools Inc.	Alberta Pressure Controls
Consolidated Oil and Gas Inc.	Cold Lake Pipe Line Co. Ltd.
Drilco Service Ltd. (Drilco Oil Tools Inc.)	Hoover Tool Joint Services Ltd.
Royalite Oil Co. Ltd.	Western GMC Truck Centre Ltd.
Shell Oil Co. Ltd.	Bradfield Fertilizer Chemical
1967	
Angelus Petroleums (1965) Ltd.	Norart Minerals Ltd.
French Petroleum Co. of Canada Ltd.	Taurus Oil Co. Ltd.
Hudson's Bay Oil and Gas Company Limited	Blue Flame Propane Ltd.
	Allied Propane Ltd.
	Economy Propane Ltd.
Shell-Royal Dutch-Shell Group	Webster (Group of Companies)
	Canadian Import Ltd.
	Liquifuels Ltd.
	Weaver Oil Ltd.
	Weaver Coal Ltd.
Superior Oil Co.	McIntyre Porcupine Mines Ltd.
1968	
Clark Canadian Exploration Company	Amherst Canadian Oil Co.
Imperial Oil Limited	Poli-Twine Corp. Ltd.
Panoil Co.	Lowe Petroleum Engineers, Inc.

TAKEOVERS, 1969

FOREIGN TAKEOVER OF CANADIAN CONTROLLED COMPANIES

Acquiring Company	Acquired Company
American Eagle Petroleums Ltd.	Penwa Oils Ltd.
Ashland Oil Inc.	W.B. Bennet Paving & Materials Ltd.
Bow Valley Industries Ltd.	Griffiths Bros. Drilling Ltd.
Bralorne Oil & Gas Ltd.	Carleton Oil & Gas Development Co. Ltd.
Canadian Hydrocarbons Ltd.	South Eastern Utilities Ltd.
Great Basins Petroleum Co.	Columbian Northland Exploration Ltd.
Manhattan Gold Mines Co.	Kodiak Petroleums Ltd.
	Royal American Petroleums Ltd.
Spelman Prentice	Bluewater Oil and Gas Limited
Ultramar Co. Ltd.	Gauthier Group

FOREIGN TAKEOVER OF FOREIGN CONTROLLED COMPANIES

Acquiring Company	Acquired Company
Ashland Oil Inc.	White Hall Canadian Oil Ltd.
Bow Valley Industries Ltd.	Elworthy and Co.
Canadian Hydrocarbons Ltd.	Golfe Oxygène Ltée
Delhi International Oil Corp.	Blue Crown Petroleums Ltd.
Great Basins Petroleum Co.	Guyer Oil Co.
Rainbow Pipeline Co. Ltd.	Mitsue Pipeline Ltd.
Reserve Oil and Gas Company	Millsion Oil Development Ltd.
Ultramar Company Ltd.	Gérard Hébert Ltée

CANADIAN TAKEOVER OF CANADIAN CONTROLLED COMPANIES

Acquiring Company	Acquired Company
Canadian Industrial Gas & Oil Ltd.	Ranvik Oils Ltd.
Chieftain Development Co. Ltd.	Engineering Specialties (Alberta) Ltd.
Kamalta Exploration Ltd.	New Marvel Oils Ltd.
New Brunswick Electric Power Commission	Black's Harbour Power Co. Ltd.
Shully's Industries Ltd.	Monarch Fuel Oil Ltd.
Trans-Canada Resources Ltd.	Drilling Fluid Service Ltd.
Twin Richfield Oils Ltd.	Golden Spike Western Petroleums Ltd.
	Twin Oils Ltd.
Westburne International Industries Ltd.	United Westburne Industries Ltd.
	Commonwealth Petroleum Services Ltd.
	Trimac Transportation Ltd.

CANADIAN TAKEOVER OF FOREIGN CONTROLLED COMPANIES

Acquiring Company	Acquired Company
Northern and Central Gas Corp. Ltd.	Augusta Natural Gas Ltd.

TAKEOVERS, 1970

FOREIGN TAKEOVER OF CANADIAN CONTROLLED COMPANIES

Acquiring Company	Acquired Company
Ashland Oils Inc.	Canadian Gridoil Ltd.
Lochaber Oil Corporation Ltd.	Bueno Oils Ltd.
Mana Resources Inc.	Garrity & Baker Drilling Company

FOREIGN TAKEOVER OF FOREIGN CONTROLLED COMPANIES

Acquiring Company	Acquired Company
Bow Valley Industries Ltd.	Syracuse Oils Ltd.
Bralorne Oil & Gas Ltd.	Junior Oils Ltd.
Dome Petroleum Ltd.	Producers Pipelines Ltd. (and its subsidiary: Westspur Pipe Line Co.)

CANADIAN TAKEOVER OF CANADIAN CONTROLLED COMPANIES

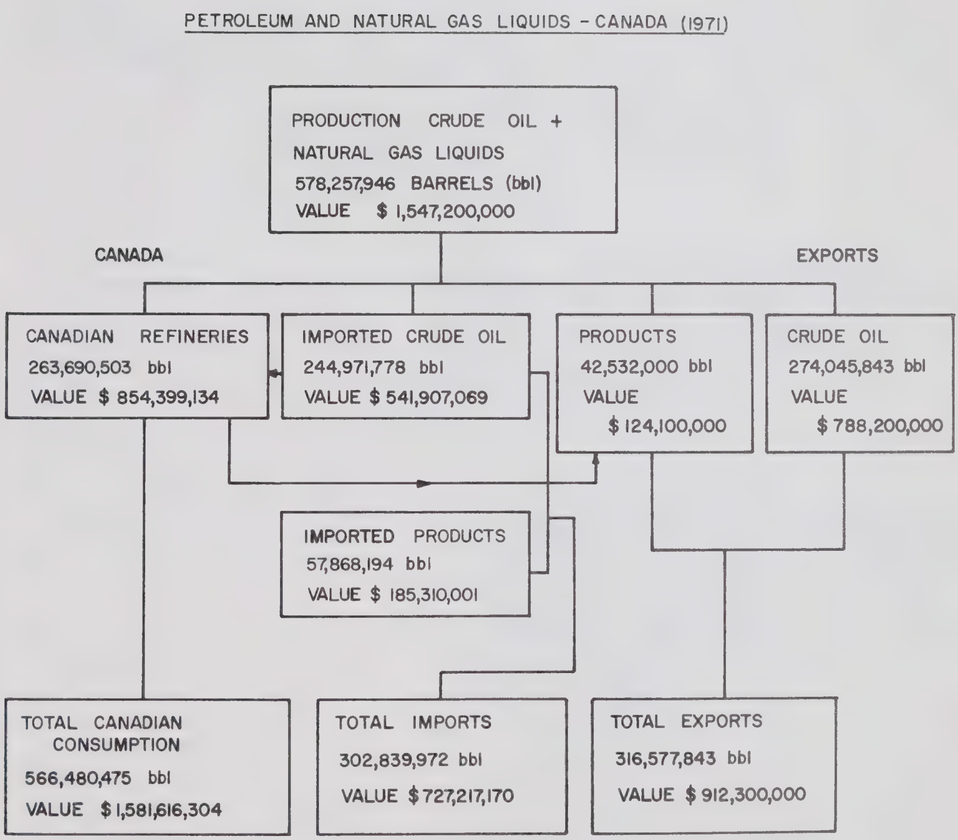
Acquiring Company	Acquired Company
Acroll Oil & Gas Ltd.	Omega Hydrocarbons
Brascan Ltd.	Mikas Oil Company Ltd.
Canada Northwest Lands Ltd.	Bayou Petroleums Ltd. Nassau Petroleums Ltd.
Chieftan Development Company Ltd.	Lloydminister Gas Company Ltd.
Edgewater Mining Co. Ltd.	Midway Oil and Gas Inc.
Ensign Oils Ltd.	Bluenose Oils Ltd.
Oakwood Petroleums Ltd.	Marwood Petroleum Ltd.
Peyto Oils Ltd.	Giant Reef Petroleums Ltd.
Ranger Oil (Canada) Ltd.	Bralsaman Petroleums Ltd.
Trimac Transportation Ltd. (subsidiary of Westburne International Industries Ltd.)	Willock Truck Equipment Co. Ltd.
Ulster Petroleum Ltd.	New Marvel Oils Ltd.
Westburne International Industries Ltd.	Trio Drilling Ltd.

CANADIAN TAKEOVER OF FOREIGN CONTROLLED COMPANIES

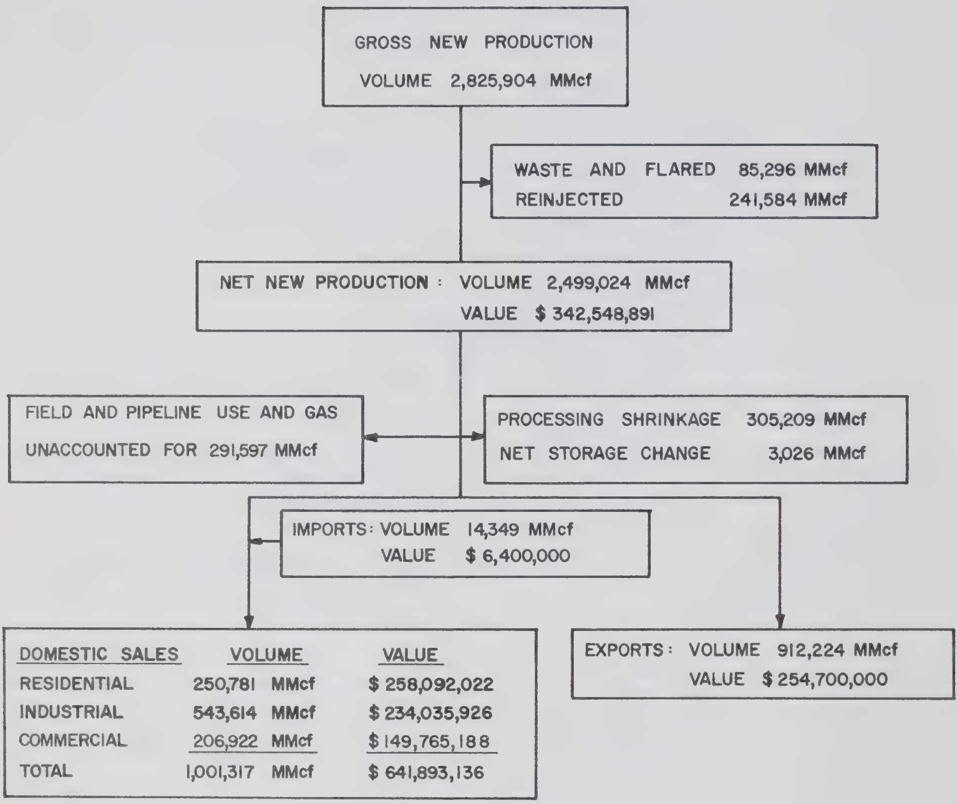
Acquiring Company	Acquired Company
Polymer Corporation Ltd.	Com-share (Canada) Ltd.
Sogepet Ltd.	French Petroleum Co. of Canada Ltd.

Chapter 3

TRADE PATTERNS—OIL AND NATURAL GAS, 1971



NATURAL GAS - CANADA - 1971



Chapter 4

CITIZENSHIP OF DIRECTORS AND SENIOR OFFICERS OF THE ENERGY INDUSTRIES

1970
(202 Companies)*

	Canadian Citizens	Resident Foreigners	Non Residents	Total Persons
Chairmen	54	2	18	74
Presidents	123	30	17	170
Vice Presidents	388	75	89	552
Other Officers	447	28	43	518
Directors (other than above)	567	45	395	1,007
	1,579	180	562	2,321

1966
(205 Companies)

	Canadian Citizens	Resident Foreigners	Non Residents	Total Persons
Chairmen	48	2	20	70
Presidents	107	37	21	165
Vice Presidents	295	77	67	439
Other Officers	452	28	59	539
Directors (other than above)	566	51	330	947
	1,468	195	497	2,160

1962
(200 Companies)

	Canadian Citizens	Resident Foreigners	Non Residents	Total Persons
Chairmen	44	3	11	58
Presidents	96	46	19	161
Vice Presidents	226	63	45	334
Other Officers	417	40	46	503
Directors (other than above)	531	77	418	1,026
	1,314	229	539	2,082

*Some persons are officers or directors of more than one company.

Canadian Controlled Companies

1970
(67 Companies)*

	Canadian Citizens	Residents Foreigners	Non Residents	Total Persons
Chairmen	32	1	4	37
Presidents	59	5		64
Vice Presidents	164	16	19	199
Other Officers	158	9	7	174
Directors (other than above)	321	18	51	390
	734	49	81	864

1966
(76 Companies)

	Canadian Citizens	Resident Foreigners	Non Residents	Total Persons
Chairmen	31	2	5	38
Presidents	62	5	4	71
Vice Presidents	132	16	6	154
Other Officers	196	6	7	209
Directors (other than above)	333	25	42	400
	754	54	64	872

1962
(81 Companies)

	Canadian Citizens	Resident Foreigners	Non Residents	Total Persons
Chairmen	30	3	2	35
Presidents	62	7	3	72
Vice Presidents	110	12	6	128
Other Officers	196	8	3	207
Directors (other than above)	310	36	54	400
	708	66	68	842

*Some persons are officers or directors of more than one company.

Foreign Controlled Companies

1970
(135 Companies)*

	Canadian Citizens	Resident Foreigners	Non Residents	Total Persons
Chairmen	22	1	14	37
Presidents	64	25	17	106
Vice Presidents	224	59	70	353
Other Officers	289	19	36	344
Directors (other than above)	246	27	344	617
	845	131	481	1,457

1966
(129 Companies)

	Canadian Citizens	Resident Foreigners	Non Residents	Total Persons
Chairmen	17		15	32
Presidents	45	32	16	93
Vice Presidents	163	61	62	286
Other Officers	256	22	52	330
Directors (other than above)	233	26	288	547
	714	141	433	1,288

1962
(119 Companies)

	Canadian Citizens	Resident Foreigners	Non Residents	Total Persons
Chairmen	14		9	23
Presidents	34	39	15	88
Vice Presidents	116	51	39	206
Other Officers	221	32	43	296
Directors (other than above)	221	41	364	626
	606	163	470	1,239

*Some persons are officers or directors of more than one company.

APPENDIX B

PART 3. EXAMPLES OF STATE PARTICIPATION IN THE PETROLEUM INDUSTRY

Appendix B—Part 3

EXAMPLES OF STATE PARTICIPATION IN THE PETROLEUM INDUSTRY

The United Kingdom

British Petroleum (BP) is one of the world's largest integrated oil companies and operates throughout the world in more than 80 countries. It is almost 50 per cent owned by the government of the United Kingdom. Originally a private venture (Anglo-Persian Oil Company) formed in 1901 to exploit a concession in Persia, the company was successful in finding oil in 1908 and in 1914 the British government bought controlling interest.

It was Sir Winston Churchill, then First Lord of the Admiralty, who promoted the acquisition of an interest in the company. Two months before the start of World War I parliament granted approval after a spirited debate headed by Churchill.

The major single government concern was to provide the British Navy with a secure source of oil under British control. Churchill argued that, if the navy had their own supply of oil they would no longer need to rely on a world market dominated by two gigantic corporations. Long-term requirements in war and peace would be assured at reasonable prices.

From this small beginning the company continued to expand in many parts of the world and in diverse areas of activity. Generally speaking the U.K. government does not participate or interfere with the commercial management of the company. However, throughout the history of British Petroleum it is clear that weight of U.K. power and influence in the world has been used to protect and ensure the best interests of the company.

British Petroleum accounts for about one quarter of the petroleum product marketed in the United Kingdom. There is little evidence to suggest that the company has been used by the government to enhance competition in the marketplace or to achieve other domestic policies.

It should be noted that British Petroleum is one of the top ten petroleum companies active in Canada with about 15 per cent of the gasoline market in Ontario and Quebec. B.P. Canada Ltd. has interests in about 50 million acres under permit or lease in Canada.

France

In 1920 the British government signed an agreement (San Remo agreement) with the French government which awarded to the French, 25 per cent of a company

holding oil concessions in Iraq. This portion of the company was previously owned by German interests before World War I. In 1924 the French government formed a quasi-governmental corporation called Compagnie Française des Pétroles (C.F.P.) to hold its 25 per cent interest in the Iraqi venture. Today C.F.P. is owned 35 per cent by the French government and the government has a 40 per cent voting control. Over the years C.F.P. has expanded and is now the 8th largest integrated oil company in the world.

In 1958 substantial discoveries of oil were made in French Algeria. The group of government sponsored oil companies formed to exploit and market franc zone crude oil eventually merged into the French national company known as Elf/ERAP which is 100 per cent owned by the French government. The government exerts greater control over Elf/ERAP than C.F.P. which operates more or less independently.

The principal objectives of French government oil policies have been to encourage French companies (chiefly C.F.P. and Elf/ERAP) to develop and control crude resources equal to French domestic oil consumption; to gain and maintain 50-60 per cent of the domestic oil product market and to develop refining and marketing interests in foreign countries equal to the participation which foreign firms have in France.

In order to achieve the goals of self-sufficiency and French majority control over domestic refining and distribution, the government has had to resort to a number of regulatory interventions affecting the French oil sector. As far back as 1928 the government was granted monopoly power over the French industry but in practice the right to conduct oil activities was "delegated" to private (and later public) enterprise. However, the monopoly powers of the government have given it the necessary legal authority to regulate the industry.

The essential elements of government intervention during the past two decades have been to establish quantitative import controls and exercise control over refining and marketing facilities. These controls have tended to favour the newcomer, Elf/ERAP, relative to the other established oil companies.

French policy has also required international refining companies in France to purchase a large part of ERAP's franc zone production at fairly high prices. In addition the government has granted tax-supported financial contributions to Elf/ERAP and given preferential treatment to the French tanker fleet.

These regulations have been largely effective in achieving the primary policy goals set out by government. This is not to suggest, however, that the highly protective French market controls have not had significant national costs associated with them.

On balance, the French government has felt it necessary to take a very activist role in oil matters. Although the reasons for this activism are various, they include:

1) large oil discoveries by French oil companies in what was then colonial Algeria;

2) a suspicious posture towards the major "Anglo-Saxon" oil companies and consequently the perceived need to maintain a French competitive balance in domestic markets;

3) a foreign policy which emphasized the creation of special links between France and the oil producing "third world"; and

4) finally, prestige in having a French standard-bearer in the strategic and highly visible oil industry.

Both French companies are active in Canada. A company of the Elf/ERAP group, Aquitaine of Canada, which acquired an interest in Banff Oil Ltd., produced 22,000 barrels per day of oil and 29 million cubic feet of gas per day in Alberta in 1971. This group has a certain interest in about 89 million acres of the total federal and provincial lands issued under permit or lease. A company of the C.F.P. group, TOTAL Petroleum (North America) Ltd. has a certain interest in holdings covering 33 million acres.

Italy

Italy's national oil company E.N.I. (Ente Nazionale Idrocarburi) is the largest national oil company (wholly government owned) in the world.

Italy is an energy short country. With the exception of some hydroelectric power and natural gas, most of her energy is imported. The Italian government, in an attempt to find hydrocarbon resources in Italy, subsidized both domestic and foreign companies in exploration activities. After many years without success the Italian government, in 1926, created a state company to conduct exploration throughout Italy. For about 20 years this company tried, with little success, to find commercial deposits of oil and gas. In the chaos of the post-war period in 1947 a prominent political figure, Enrico Mattei, was put in charge of the state organization. In 1949 gas was discovered in the Po Valley and the foundation was set for the rapid expansion of the Italian national oil company both in and outside of Italy.

It must be understood that originally E.N.I. was not conceived or shaped by state planners, or effectively controlled by agents of the state. In the first ten years of its growth it was largely an extension of the ambitions and philosophies of one man. Enrico Mattei was a highly ambitious Italian nationalist. Shortly after the Po Valley discoveries he convinced the Italian state, against much opposition, that the state company ought to be given a monopoly position on hydrocarbons in the Po Valley. The exercise of this monopoly position provided Mattei with the financial resources to expand. Mattei was a strong opponent of the international oil club and actively promoted contact with "third world" countries in order to develop joint venture refining and marketing activities for crude oil exploration and production.

Today E.N.I. is a highly respected member of the international oil community with a wide range of oil and non-oil activities throughout the world. However, if one measures E.N.I.'s performance simply by conventional financial results, one would have to agree that the company has not been greatly successful. The basic proposition here is that E.N.I. cannot be judged as a private corporation. It is most important to recognize that the company has been used by the state, in part, as an instrument of domestic economic development. For example, E.N.I. has been pressed by the state to expand facilities in depressed areas of southern Italy.

Refinery construction and other activities have created a nucleus for industrialization. These contributions by E.N.I. to the national economy are difficult to quantify.

The fact that the Italian state is heavily involved in the petroleum industry has given the government a high degree of understanding in the highly complex international petroleum industry. It is difficult to quantify the value of being well-informed in the oil business, but in a rapidly changing international oil economy some benefits must accrue to those parties who more clearly understand current developments and future trends.

E.N.I. has about a quarter of the petroleum product market in Italy and is apparently satisfied with this share. The company competes with other foreign and domestic companies in Italy.

There are many other countries in which state participation in the oil industry is a significant factor. Countries with national oil companies are more nearly the rule today rather than the exception. Although North American attitudes tend to limit government participation in industrial affairs, most other parts of the world do not have the same ideological inhibitions against government initiatives and many nations look with favour upon government ownership in energy industries.

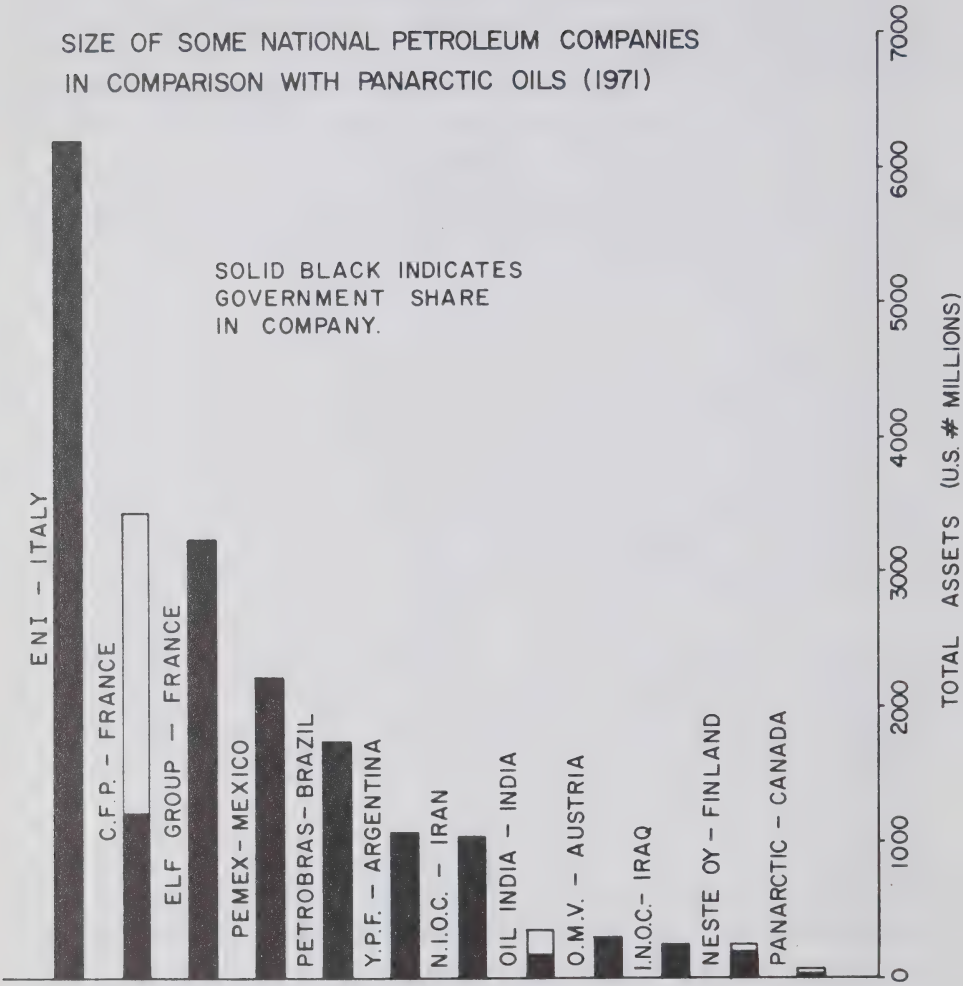
Norway

A recent entry into national oil company ranks has been the Norwegian State Oil Company. Norway has had a long tradition of government participation in basic industry. With the discovery of oil in the Norwegian sector of the North Sea the Norwegian government took aggressive action to ensure that oil developments would be under terms and conditions which maximized the benefits to the nation. The pace of development in Norway will be dictated by the government. A very large amount of offshore territory has yet to be opened for exploration and it is likely that the Norwegian State Oil Company will take a very active role in future developments. The formation of a wholly-owned state petroleum company was a natural development in Norway. Expansion of their technical capabilities was probably a prime motivating force. A general suspicion of large international oil companies and the desire to exercise control over these oil companies also contributed towards the decision to develop a state entity.

Canada

Panarctic Oils Ltd. is not a Crown corporation. Essentially, it is a company whose shares are held by the federal government and more than twenty other investor groups. The federal government's share interest is approximately 45% of the common equity stock. The balance of the investors, almost all of whom are Canadian-controlled companies, hold 55% of the common equity stock. The majority of the Directors of Panarctic have been elected by the shareholders from the business sector. A minority of Directors, four in number, have been elected from the Public Service. The management of Panarctic was recruited by the company entirely from the petroleum industry and few had any background in government service.

In a sense, Panarctic is a joint venture between the Canadian business community and the Canadian government to achieve somewhat different, but mutually


SIZE OF SOME NATIONAL PETROLEUM COMPANIES
IN COMPARISON WITH PANARCTIC OILS (1971)
SOLID BLACK INDICATES
GOVERNMENT SHARE
IN COMPANY.
ENI - ITALY
C.F.P. - FRANCE
ELF GROUP - FRANCE
PEMEX-MEXICO
PETROBRAS-BRAZIL
Y.P.F. - ARGENTINA
N.I.O.C. - IRAN
OIL INDIA - INDIA
O.M.V. - AUSTRIA
I.N.O.C.- IRAQ
NESTE OY - FINLAND
PANARCTIC - CANADA
0
1000
2000
3000
4000
5000
6000
7000
TOTAL ASSETS (U.S. # MILLIONS)

compatible goals. Panarctic as a project originated in the mid-1960's as a way of bringing about exploration and development on federal oil and gas permits in the Arctic Islands, then held largely by a considerable number of Canadian independent companies. The major integrated oil companies did not accord the Arctic Islands an important priority for development at that time. By 1967, it became clear to the Government of Canada that unless the government played a financial role in launching a major exploration program, there would be no serious efforts in the Arctic Islands for some years. Accordingly, a combination of government and private funds was organized and significant discoveries of natural gas have been made in what remains today as an early part of the exploration phase. It is not unreasonable to expect that commercial quantities of natural gas may be defined within Panarctic's holdings in the Arctic Islands within two to four years.

The private investors in Panarctic no doubt saw for themselves, in making the investment, an opportunity to participate in exploration which could have high rewards over the longer term. It was also exploration with as high a degree of risk as any in Canada. The reward to the private sector comes only with the commencement of a cash flow from production. No doubt the interest of the government in participating, based on long-term national policy consideration, was a significant incentive to most of those in the private sector to play a role.

For its part, the government had two major objectives in entering the Panarctic investment:

> To come to the assistance of an important part of the Canadian-owned corporate activity in the petroleum industry. These companies had invested substantial funds, but perhaps had underestimated the cost of carrying out the work obligations under the permits. Many were, however, willing to proceed if some appropriate form of risk sharing could be worked out. The alternatives to government were to take back the permits with the likelihood of little private sector activity in the area by Canadians or finance a program entirely by government, or turn the permits over to a few foreign-owned companies with the financial capability of conducting the work. The government decided to go along with a joint effort with a group of Canadian companies.
>
> The government felt a strong need for a better definition of the resource potential of the Arctic Islands for oil and gas. This information is significant both to longer term policies by government for northern development and the economic support of the people in the north, and also for broader long-term policies in connection with the availability of domestic sources of supply of energy, both to the Canadian and export markets. It was considered very much in the interests of Canada not to delay exploration for several years.

Thus, in the view of government, Panarctic is not simply a commercial venture, but one with broad public policy goals which have proven to be compatible with the commercial interests of the private business companies who make up the majority of the shareholding. Panarctic is managed entirely according to the techniques and concerns of the private business community and in ways which give it no unfair commercial advantage over other private companies which are engaged in oil exploration.

APPENDIX C

APPENDIX C

THE ENERGY INDUSTRIES OF CANADA

Foreword

This Appendix contains a series of papers describing the energy industries of Canada. These papers have not been prepared with the objective of having a completely comparable coverage of each of the individual industries but rather are presented as complementary material to the main report.

Chapter 1

THE COAL INDUSTRY OF CANADA

REVIEW OF THE INDUSTRY

The resurgence in coal demand is of recent date and the impact of escalating market requirements is placing considerable strain on an industry that is only now recovering from several decades of depression during which it lost much of its management expertise, skilled labour and capacity to produce. Since the beginning of its recovery in the late 1960's, the industry has faced the necessity of rebuilding itself from a narrow residual basis of these human and material assets. This has been an arduous and lengthy process, not yet completed, and is one of the fundamental reasons why an important section of the industry, namely the western metallurgical mines, has encountered serious technical and financial problems that have hindered them from meeting their expanded markets and attaining economic viability.

The lengthy and recently ended depression period for coal was the result of several causes. Principally, and beginning in the late 1940's there were the massive new discoveries of oil and natural gas in Western Canada followed, in the early 1960's, by the appearance of imported oil, at low prices, in the Atlantic Provinces and Quebec. These competing fuels, both native and imported, were available throughout the 1950's and 1960's in massive quantities and at low prices. In addition, there continued to exist an inflow of coal, at low prices, into central Canada from the nearby coal fields of the United States. This mix of formidable competition effectively reduced the Canadian coal industry to insignificant proportions in both western and maritime Canada. Negative factors also existed within the coal industry itself. These included the long distance between the coal fields and the main energy markets of industrialized central Canada, leading to high transportation costs, and the inefficiencies of the aging collieries of maritime Canada.

The present resurgence in the use of coal resources is the result of changes taking place in the national and international markets for energy and metallurgical fuels. The rising global demand for energy is straining the finite supplies of economically available oil, natural gas and hydro and there is a growing international awareness that greater use must be made of coal resources which are available in vastly greater quantities. In this connection, coal resources are measur-

able in terms of centuries of supply rather than of decades. Even with the forecasted large contribution from nuclear power during the balance of this century there will still remain a very large segment of total energy demand that must be filled by fossil fuels. It would appear that, globally, we are entering an era of potential energy shortages and, certainly, of strongly rising energy prices.

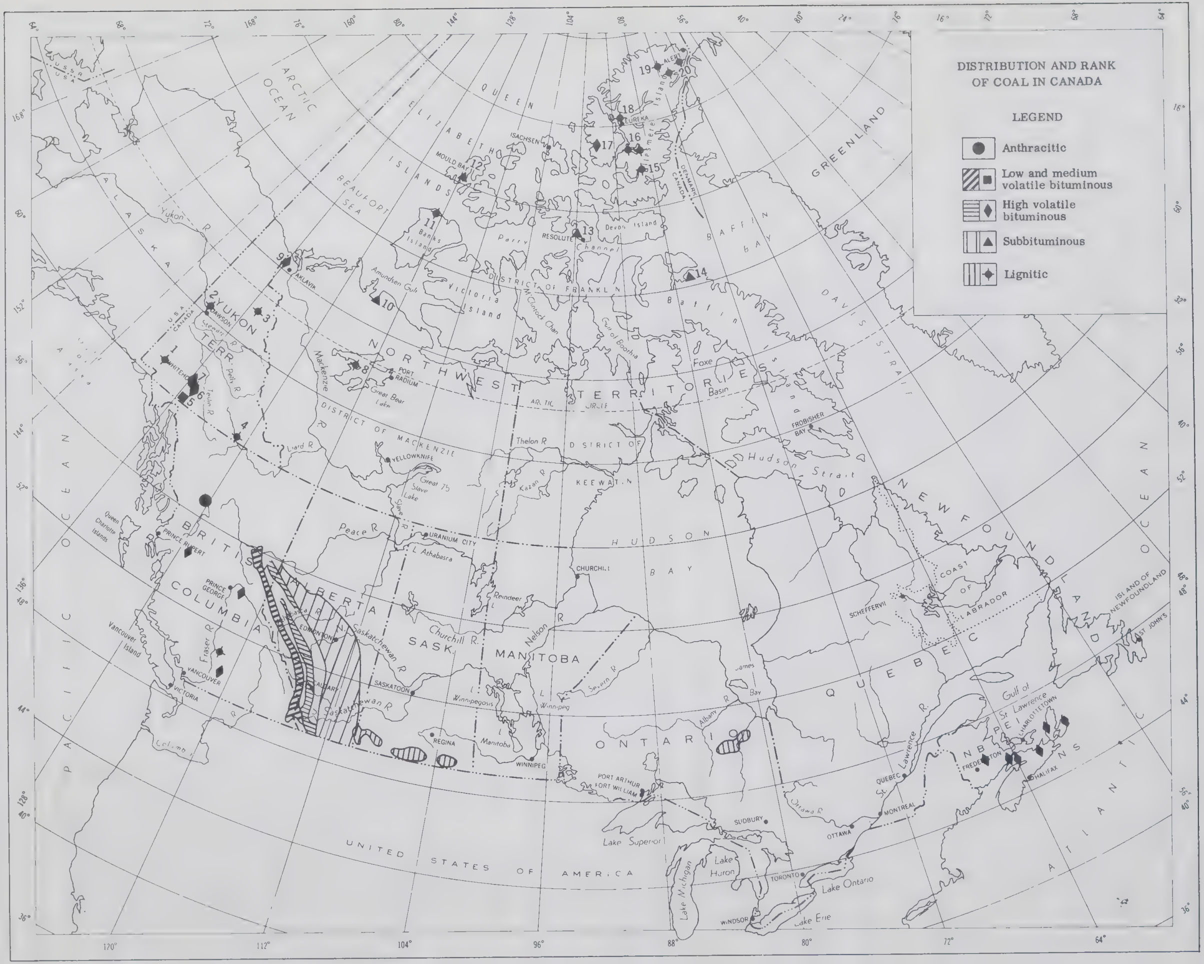
A second and important reason for the renewed interest in coal resources is the worldwide shortage of good quality metallurgical coal for the strongly growing steel industries. This shortage does not arise from a geological lack of metallurgical quality coals, because there are immense reserves in many countries, but it arises because of the inability of most countries to produce it economically. For example, the ancient coal industries of Europe and Japan cannot produce coal at competitive prices but the operators of the United States, Australia and, hopefully, Canada can do so.

A third and future reason for the growing interest in coal is its conversion into liquid and gaseous fuels to supplement the global supplies of these relatively scarce materials. The related processes are under active study in the United States where such conversion will likely make its first commercial appearance. The economic possibilities of such conversion in Canada now appear to be of somewhat later timing.

The emerging pattern, as we complete this Twentieth Century is that the industrialized nations will no longer use fuel in random fashion but more in rational accordance with the quantity of each type of energy available to them. To date, we have been prodigal in the use of our higher quality fuels. For example, there is the current use of natural gas and low sulphur oils for raising steam in thermal electric plants. These relatively scarce and high quality fuels have other and nationally more rewarding uses but they are now being employed for steam raising because they are free of the sulphur and flyash problems associated with coal burning. Admittedly, this provides a quick answer to an immediately pressing ecological problem but it also highlights the present poverty of research related to the use of coal.

It is in the national interest to begin an orderly, long-term and more balanced use of all Canada's energy resources. Toward this end it is vitally necessary to end the scientific lag in the production, processing, transportation and use of coal resources by promoting research and development related to coal.

The minimum target for 1980 should be a Canadian coal production in the order of 37 million tons per annum. This will be barely adequate to take care of rising national demand plus a normal growth of the export market. In contrast, production during the 1960's averaged about 11 million tons per year. Demand is already escalating as evidenced by the sharp rise of production to 20.6 million tons in 1972, but this level of production is being accomplished only with considerable difficulty because of unsolved technical problems. The attainment of the 37 million ton target, with its beneficial effects on employment, national self-sufficiency in energy and on balance of payments, cannot be expected to occur automatically. It can best be achieved if policies and planning are instituted on a national-wide scale in which the federal government acts in liaison with the provinces and industry.


DISTRIBUTION AND RANK OF COAL IN CANADA
LEGEND
Anthracitic
Low and medium volatile bituminous
High volatile bituminous
Subbituminous
Lignitic
ARCTIC OCEAN
BEAUFORT SEA
QUEEN ELIZABETH ISLANDS
GREENLAND
BAFFIN BAY
DAVIS STRAIT
Hudson Strait
HUDSON BAY
NORTHWEST TERRITORIES
DISTRICT OF FRANKLIN
DISTRICT OF MACKENZIE
DISTRICT OF KEEWATIN
YUKON TERR.
ALASKA
BRITISH COLUMBIA
ALBERTA
SASK.
MANITOBA
ONTARIO
QUEBEC
NEWFOUNDLAND
COAST OF LABRADOR
N.B.
P.E.I.
N.S.
UNITED STATES OF AMERICA
PACIFIC OCEAN
ATLANTIC OCEAN
Banks Island
Victoria Island
Devon Island
Amundsen Gulf
Gulf of Boothia
Foxe Basin
Baffin Island
Parry Channel
M'Clintock Chan.
ISACHSEN
MOULD BAY
RESOLUTE
EUREKA
ALERT
AKLAVIK
DAWSON
WHITEHORSE
PORT RADIUM
YELLOWKNIFE
URANIUM CITY
CHURCHILL
FROBISHER BAY
PRINCE RUPERT
PRINCE GEORGE
EDMONTON
CALGARY
SASKATOON
REGINA
WINNIPEG
VANCOUVER
VICTORIA
PORT ARTHUR
FORT WILLIAM
SUDBURY
OTTAWA
MONTREAL
QUEBEC
TORONTO
WINDSOR
SCHEFFERVILLE
FREDERICTON
CHARLOTTETOWN
HALIFAX
ST. JOHN'S
ISLAND OF NEWFOUNDLAND
Great Bear Lake
Great Slave Lake
L. Athabasca
Reindeer L.
L. Winnipeg
L. Winnipegosis
L. Manitoba
Lake Superior
Lake Michigan
Lake Huron
Lake Erie
Lake Ontario
James Bay
Gulf of St. Lawrence
Queen Charlotte Islands
Vancouver Island
Yukon R.
Mackenzie R.
Peace R.
Slave R.
Thelon R.
Kazan R.
Churchill R.
Nelson R.
Saskatchewan R.
Fraser R.
Columbia R.
Liard R.
Pelly R.
Stewart R.
Teslin R.
Severn R.
Albany R.
Ottawa R.
St. Lawrence R.
ARCTIC CIRCLE
U.S.A.
CANADA
U.S.S.R.
DENMARK
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The Federal Role

Progressively, over the past few years, the federal role has changed from one of supplying direct aid to the industry in the form of subvention payments and low cost loans, to one of concentrating on research and development related to the technical and economic problems that now restrict the industry. It is believed that this new approach to coal resources will be of greater and more lasting benefit to the industry as well as promoting a more orderly exploitation of this massively present resource.

The federal government, principally through the Department of Energy, Mines and Resources, has long been engaged in programs relating to coal development as evidenced by the following sections.

Subventions. Federal subvention aid was initiated in 1928 and terminated on March 31, 1971. During this period, the total aid thus provided was as follows:

	Subvention	Tons Subvented
On Nova Scotia coal	$247,523,616	69,826,525
On New Brunswick coal	10,450,136	4,009,575
On Saskatchewan coal	3,465,504	5,118,058
On Alberta coal	49,336,538	22,391,668
On British Columbia coal	16,658,855	5,895,085
Total Aid	$327,434,649	107,240,911

The basic objective of these subventions was to enable Canadian coal to be sold at a price competitive with that of foreign fuels.

The subventions remained at relatively modest amounts until the 1960's, at which time a sharp escalation occurred principally because of the appearance, in the Atlantic Provinces and Quebec, of massive quantities of imported oil at low prices. This required the federal government to expand its subvention policy by paying subvention on Maritime coal marketed within the Atlantic Provinces and not, as previously, in Quebec and Ontario only. An additional reason for the escalation was the inefficiency of the aging coal industry of the Maritimes. A lesser increase occurred in Western Canada and was related to promotion of the Japanese market.

Undoubtedly, this federal program of subvention aid had a certain value over the years in preventing a series of abrupt and politically unacceptable social disruptions of the dependent communities, but it must inevitably be regarded as a prolonged emergency measure that held little promise of effecting an acceptable solution.

In Western Canada, the subventions were finally ended in 1971 because of the market created for metallurgical coal in Japan (promoted with subvention aid) and the rising demand by the electric utility plants of the Prairies for lignite and sub-bituminous coals.

In Nova Scotia, the subventions ended in 1968 when the major coal mines were taken over by the Cape Breton Development Corporation on a basis of phasing down coal production and introducing other industries to support the local economy. Financial responsibility for the smaller Nova Scotia mines was assumed in 1968 by the province.

The Government of New Brunswick took over the whole provincial coal industry in 1968 and formed the Grand Lake Development Corporation* for that purpose. The provincial objective is to phase down its coal industry while introducing new industries. It has been aided in these efforts by federal grants totalling $19 million over a 5-year period ending in fiscal year 1972-73. In addition, the province was granted the rights to approximately $500,000 of federal loans granted previously to the private mine operators of that province under the Coal Production Assistance Act.

Duties on Coal. Until 1950, all imported coal was subject to a duty of 50 cents per ton.

The duty was removed from metallurgical coal at that time because the bulk of this coal was used by the steel making industry of Ontario and little, if any, Canadian coal was employed by these steel mills. Its continuing imposition would merely have constituted a financial burden on the steel makers with no corresponding benefit to Canada's coal producers.

In fiscal year 1967-68 a decision was made to remove this duty on the rest of the imports which were used for electrical generation and other power purposes, space heating, etc. The decision was to reduce the duty progressively by 10 cents per ton per year until its elimination over a 5-year period. The first increment of reduction was made on January 1, 1968. However, this rate of reduction was accelerated in 1969 and the duty was completely eliminated on June 4 of that year.

During the time of its application this duty was of minor importance and effect in promoting the national use of Canadian coal. Other and more major forces restricted the use of Maritime and Western Canada coals in central Canada. These included the low efficiency and high costs of the native coal industry, coupled with the formidably high freight rates to the central market.

Federal Loans. The purpose of these loans, granted under the terms of the Coal Production Assistance Act, was to modernize and mechanize Canadian coal mines to enable them to improve productivity and costs.

The loans bore interest at rates earned by federal government bonds of comparable term.

Between its inception in 1949 and the abolition of this Act in 1970, the history of these loans is as follows:

Loans repaid	26
Loans being repaid	1
Loans transferred to New Brunswick	3
Loans written off	1
Total loans made	31

* The coal mining subsidiary of this provincial crown agency is N.B. Coal Limited.

Repayment Position (1972)

	Dollars	Per cent
Amount repaid	$13,549,314.00	82.3
Amount being repaid (1972)	2,352,000.00	14.3
Loans transferred to New Brunswick*	513,701.93	3.1
Balance on loan written off	39,989.46	0.3
Total amount loaned	$16,455,005.39	100.0

*Loan balance on transfer date, December 1968.

In addition to the above repayments on principal, the recipients paid interest totalling $5,617,265.54 as of 1972.

Canadian Coal Equality Act. This Act was proclaimed in 1930 and repealed in 1970. The purpose of the Act was to promote the use of Canadian coal in the Canadian iron and steel industry, by paying these consumers the sum of 49½ cents for each ton of Canadian bituminous coal converted by them into coke for the manufacture of iron and steel.

Between 1930 and cessation in 1970, federal payments to the iron and steel producers were:

Tons of Coal Assisted	*Aid Provided*
20,209,658	$10,003,780

Other Forms of Federal Financial Aid. During the past four decades the federal government provided additional financial assistance to the Canadian coal industry under a number of other programs of various time durations and in different amounts. For brevity, these are merely listed below, but a more detailed description of the purpose and timing of each program is contained in the Report of the Royal Commission on Coal (Rand Commission) of 1960.

Aid under the Atlantic Provinces Power Development Act.

Government Directives respecting preferences for Canadian coal in federal heating plants.

Stockpile Reduction Program at Sydney, N.S. (1958).

Springhill Colliery Assistance Order, 1957.

The Domestic Fuel Act (1927-1932) to subsidize construction of coking plants.

Emergency Coal Production Board (1942-46), related to wartime subsidies, grants and loans to promote coal production.

The Lignite Utilization Board (1917-1923), jointly sponsored by federal, Saskatchewan and Manitoba governments to develop new uses for lignite coal.

Benefits under the Maritime Freight Rates Act.

Technical Advice and Laboratory Services. The federal government has been providing this form of aid throughout most of this century principally via the Department of Energy, Mines and Resources (under a succession of names) and through the agency of the Dominion Coal Board until its dissolution and absorption by Energy, Mines and Resources in 1970.

This aid has been applied in these fields of investigation:

Geological mapping and estimates of coal reserves.

Determination and classification of coal quality.

Studies of mining problems related to the extraction of coal.

Investigations into the problems of washing and preparing coals for marketing.

Studies into improving the coking qualities of metallurgical coal.

Investigations into up-grading the quality of sub-bituminous and lignite coals to develop new uses and wider marketability.

Studies for improving the combustion characteristics for the steam coal market.

Assistance in market development, for example, the Japanese market.

Assistance in studies related to more efficient bulk transport of coal including unit trains and pipelines.

In furtherance of these activities the Department established a Coal Branch in its Energy Development Sector with responsibilities for developing federal policies and for coordinating federal programs related to coal resources. At the technical operational level, the Department maintains coal services in the following establishments:

Mines Branch

Fuels Research Centre
Canadian Combustion Research Laboratory, Ottawa
Canadian Explosive Atmospheres Laboratory, Ottawa

Mining Research Centre, Ottawa and Calgary

Metals Reduction and Energy Centre
Metallurgical Fuel Engineering Group, Ottawa
Western Regional Laboratory, Edmonton

Mineral Resources Branch
Mineral and Metals Division

Geological Survey of Canada
Institute of Sedimentary and Petroleum Geology, Ottawa and Calgary

The Western Regional Laboratory has been enlarged by the addition of coke oven testing facilities to improve the use of western coal in the manufacture of metallurgical quality coke. These facilities supplement the existing coking laboratory in Ottawa. The western coals are highly variable with respect to their coking characteristics and the Department has decided that additional facilities are needed if Canada is to make optimum use of these coal resources.

In cooperation with the Government of Saskatchewan the Department has begun an inventory of the amount of lignite coal that can be economically extracted under known mining techniques.

In Nova Scotia, the Department of Energy, Mines and Resources is assisting the Cape Breton Development Corporation in a number of technical and economic problems affecting the coal resources of the Sydney coal field. A test plant has been erected for developing a technique for lowering the sulphur content of the Sydney coals and thus making them more acceptable in the metallurgical market. The Department is also cooperating with the Governments of Nova Scotia and New Brunswick in their programs for rationalizing the smaller coal operations of those two provinces.

In addition to the above "in-house" activities, the Department also supports, through annual grants, coal related investigations in universities and provincial research councils.

All the above investigations are conducted with the knowledge and commonly the technical liaison of the related departments of provincial governments. As well, and in order to avoid duplication of effort, the Department maintains a strong liaison with the Canadian Advisory Committee on Coal Research which is representative of coal scientists across Canada and with the Canadian Carbonization Research Committee which is representative of the coal scientists and the steel making industries of Canada.

In summary, the federal government and specifically the Department of Energy, Mines and Resources recognizes that the coal mining industry of Canada has a number of problems affecting the production and marketing of coal and has taken substantial and meaningful steps, as summarized above, to help in their solution. The Department also recognizes that it cannot do the full job alone but earnestly seeks a continuing and greater partnership with the governments of the coal-producing provinces and with the coal-producing companies.

The Provincial Role

With some exceptions, jurisdiction over the administration and control of mineral resources lies with the governments of the provinces in which the minerals lie. This right is established under the British North America Act, Section 109.

The federal government has jurisdiction over the mineral resources of the Yukon and the Northwest Territories, as well as on federal lands, within Indian Reservations and in national park lands.

Another exception to the general control exercised by the provinces are the Dominion Coal Blocks, located in the Crowsnest Pass Coalfield of south-eastern British Columbia. These come under federal jurisdiction.

In the main, however, it is provincial legislation that governs the granting of mineral rights, the collection of mineral royalties, and the enforcement of regulations governing safety of operations and the conservation of minerals. Over the years, provincial interest and activity have been related mainly to these functions.

Historically, and until quite recently, the overall welfare of the industry has been left largely to the federal government as exemplified by the variety of aid programs described under the heading of Federal Role.

In Nova Scotia, direct financial aid was provided by the province for a brief period in the 1950's. Subsequently, beginning in 1968, the province undertook a much larger responsibility when it agreed to provide financial aid to its smaller coal companies while the federal government, via the Cape Breton Development Corporation, took over the operation of the major collieries on Cape Breton Island. This sharing of the financial burden is in accordance with the related Canada/Nova Scotia Agreement of June 13, 1967.

In New Brunswick, the provincial government took over its coal mining operations and formed the Grand Lake Development Corporation for that purpose. This is in accordance with the Canada/New Brunswick Agreement of March 26, 1968. As detailed later in this review (under the Industrial Situation) the objective of the Agreement is to reduce coal production in accordance with logical markets and to promote the development of other industries. The coal arm of this provincial Crown Corporation is known as the N.B. Coal Limited. All funds for this industrial rationalization program were supplied by the federal government.

In Western Canada the current interest of the provincial governments arises from a growing awareness of the economic potential of the export market in metallurgical coals and from a parallel awareness that coal is becoming increasingly necessary for the electric power utilities of the prairie regions. This new awareness is particularly evident in Alberta where, since the late 1960's, the government has made substantial financial contributions toward the construction of a new railroad[1] and in the establishment of a new coal mining community[2]. Alberta is also active in the promotion of technical training for the industry. The Alberta Research Council has been effective in research and development related to coal. Much less interest and active participation have been exhibited in the past by the Governments of British Columbia and Saskatchewan. More recently, as of 1972, the Province of Saskatchewan entered into a jointly supported program of resource evaluation with the federal government aimed at determining the economic potential of its lignite resources. In addition, the Saskatchewan Research Council has conducted useful coal research in cooperation with federal laboratories.

In summary, the provinces have traditionally confined themselves to their mineral leasing and royalty collecting activities and to their mine inspection services but recently, because of their growing awareness of the future value of their coal resources, they are now exhibiting a more direct concern with the broader technical, social and economic factors. For example, British Columbia contributed materially to the development of the shipping port at Roberts Bank.

The Industrial Situation

As indicated, the resurging new demand for coal is compelling the Canadian coal mining industry to rebuild itself rapidly upon the residual and limited pool of management, labour and capital that survived the several decades of depression.

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[1] The Alberta Resources Railway.

[2] The town of Grande Cache, the community associated with the McIntyre Porcupine coal mine.

Of necessity, there has been substantial inputs of foreign personnel and material assets. In addition to re-building the older mines and developing new mining ventures, there has been the necessity of enlarging and modernizing the coal freighting systems on both major Canadian railways and the development of deep sea docks. The recruitment and training of a much larger skilled work force was, and continues to be a major problem. New mining communities, with modern social facilities have had to be built and rehabilitation has been carried out in the older mining communities.

The gross effect of this abrupt growth has been a severe straining of the current capacity to produce, up-grade and transport coal. This situation is particularly severe for the bituminous mines of Alberta and British Columbia where much of the new growth is occurring. The impact has been much less severe for the Prairie mines of Saskatchewan and Alberta which experienced a lesser erosion of mining expertise and where the mining processes of coal extraction, quality up-grading and transportation are conducted under much more regular and predictable conditions.

In Nova Scotia and New Brunswick the coal industry is under public control with the broad objective of phasing down production from their historically non-economic coal mines. Initially, from the viewpoint of the late 1960's when public control was introduced, the intent was to phase out the Maritime coal industry completely over a relatively few years during which it was hoped that other industries would be attracted to provide a new economic base for the dependent communities. However, subsequent practical experience has dictated a modification of this program because of the difficulties and disappointments encountered in attracting and establishing viable other industries and also because of subsequent price increases in the energy market. The recent and emerging situation in the energy and metallurgical markets requires a careful re-evaluation of these Maritime coal resources to determine their current and future asset value as a viable source of coal to meet Canada's needs.

The public management of DEVCO in Nova Scotia and of the N.B. Coal Limited in New Brunswick are realistically assessing the industrial options now open to them for the economic rehabilitation of their assigned regions. Coal is being included in the mix of industrial options under study with the basic assumptions that improved mining techniques can be introduced, that better work attitudes can be developed, and that market prices for energy and metallurgical coals will not retreat below present levels.

The industrial situation is brightest at the surface stripping operations of Saskatchewan and the Alberta Plains region. These mines are operating with commendable efficiency and productivity. Their market is the electric generating industry of the western prairies, which is a strongly growing one. These coals can be produced and delivered to regional power plants at fully competitive costs.

Knowledge of Coal Resources

The present knowledge about Canada's coal resources is based on geological studies and determinations of coal analyses, supplemented by data obtained by the industry in its exploration and mining activities.

The most comprehensive Canada-wide report was that prepared for the Royal Commission on Coal (1946) by Dr. B. R. MacKay of the Geological Survey of Canada. As distinct from earlier estimates of Canada's coal reserves, the MacKay report did not deal with coal solely as a geological occurrence, but introduced a number of parameters in an effort to classify the coal in terms of economic availability. Such parameters disregarded coal existing in thin seams of lesser thickness than that found practical to mine under known technology, and also coal lying at depths greater than that reached in actual operations. With very few exceptions, notably in New Brunswick, all coal seams of less than 3 feet in thickness were excluded from the calculations. For the depth limitation, a maximum of 4,000 feet was adopted for Nova Scotia, 2,500 feet for the bituminous mines of Alberta and British Columbia, and 500 feet for New Brunswick, Ontario (Onakawana), Manitoba and Saskatchewan.

With the use of these limiting parameters, MacKay arrived at estimates of MINEABLE coal, constituting the tonnage of coal considered to exist in seams of mineable thickness (under existing technology) and lying within the required vertical distance below surface. His results, by provinces, were:

MINEABLE COAL
(thousands of tons)

Province	*Probable*	*Possible*	*Total*	*Per cent*
Nova Scotia	1,197,000	1,147,000	2,344,000	2.4
New Brunswick	89,800	11,500	101,300	0.1
Ontario	100,000	50,000	150,000	0.2
Manitoba	33,600	67,200	100,800	0.1
Saskatchewan	13,126,000	11,004,000	24,130,000	24.6
Alberta	34,437,000	13,436,000	47,873,000	48.8
British Columbia	11,795,000	7,034,000	18,829,000	19.2
Yukon	434,000	1,449,000	1,883,000	1.9
Northwest Territories	140,000	2,489,000	2,629,000	2.7
Canada total	61,352,400	36,687,700	98,040,100	100.%

The report thus indicated that Canada possessed about 61.35 billion tons of Probable plus about 36.69 billion tons of Possible for a total of 98 billion tons of MINEABLE coal.

Under this assessment, *probable* reserves mean coal which "by direct mining experience and by drilling, by continuity to existing workings and areas drilled, or by extensive geological data can be reasonably expected to exist".

Possible reserves mean coal, "the reasonable existence of which is based on limited geological data and limited prospecting", also coal "whose recovery is problematical due to its inferior quality and/or its relative inaccessibility".

The MacKay report then recognized that not all of this MINEABLE coal in situ would actually be extracted and brought to surface as production. To allow for this, he adopted the reasonable average recovery rate of 50 per cent and, with use of this rate, arrived at the following estimate for RECOVERABLE coal.

RECOVERABLE COAL
(thousands of tons)

Province	*Probable*	*Possible*	*Total*	*Per cent*
Nova Scotia	983,000	573,600	1,556,600	3.1
New Brunswick	44,900	5,800	50,700	0.1
Ontario	50,000	25,000	75,000	0.2
Manitoba	16,800	33,600	50,400	0.1
Saskatchewan	6,563,000	5,502,000	12,065,000	24.4
Alberta	17,218,000	6,718,300	23,936,300	48.4
British Columbia	5,897,000	3,517,200	9,414,200	19.0
Yukon	217,000	724,900	941,900	1.9
Northwest Territories	70,000	1,244,900	1,314,900	2.7
Canada total	31,059,700	18,345,300	49,405,000	100.%

With respect to the *rank* of the Canada coals, MacKay reported RECOVERABLE coal as follows:

RECOVERABLE COAL
(thousands of tons)

By Rank	*Probable*	*Possible*	*Total*	*Per cent*
Bituminous—Low Volatile	4,882,900	2,703,900	7,586,800	15
Bituminous—Medium Volatile	11,152,300	4,032,700	15,185,000	31
Bituminous—High Volatile	4,951,900	3,482,800	8,434,700	17
Sub-bituminous	3,122,600	1,155,300	4,277,900	9
Lignite	6,950,000	6,970,700	13,923,500	28
Total, all ranks	31,059,700	18,345,400	49,405,000	100

The locations of the above ranks by provinces are:

Bituminous Low Volatile	—In British Columbia and Alberta
Bituminous Medium Volatile	—In British Columbia and Alberta
Bituminous High Volatile	—In B.C., Alta., and the Maritimes
Sub-bituminous	—Plains area of Alberta
Lignite coal	—Saskatchewan, other western provinces, the Arctic and Ontario.

In summary, the MacKay report which comprises Appendix A of the Royal Commission on Coal (1946) constitutes a valid and still acceptable estimate of the coal reserves of Canada.

The MacKay report was updated in 1960 by Mr. B. A. Latour of the Geological Survey of Canada for use by the Royal Commission on Coal—1959 (Rand Commission). Fundamentally, this 1960 updating consisted of adjusting the MacKay estimates to allow for the amount of coal extracted during the intervening years.

Still later, in 1970, a re-assessment of the measured coal reserves of Western Canada was made by Mr. Latour and Mr. L. P. Chrismas of the Department of Energy, Mines and Resources. This 1970 report* constituted an early phase of the current Departmental program for conducting an inventory of all Canada's energy resources. This report categorized the coal resources of Saskatchewan, Alberta and British Columbia under the following headings:

Measured or Proven Resources

Indicated or Probable Resources

Inferred or Possible Resources

As defined in this 1970 report, MEASURED resources means coal about which so much is known that it can firmly be expected to exist and for which calculations are judged to be accurate to within, say, 20 per cent. The terms INDICATED and INFERRED correspond respectively to the *probable* and *possible* reserves of the MacKay report. The 1970 reassessment indicated as follows:

COAL RESOURCES OF WESTERN CANADA BY PROVINCES
(in billions of tons)

Province	*Measured*	*Indicated*	*Inferred*	*Total*
British Columbia	7.3	11.2	41.0	59.5
Alberta	2.2	32.1	12.9	47.2
Saskatchewan	0.3	7.0	4.7	12.0
Total	9.8	50.3	58.5	118.7

COAL RESOURCES OF WESTERN CANADA BY RANK
(in billions of tons)

Rank	*Measured*	*Indicated*	*Inferred*	*Total*
Low and Medium Volatile	7.93	30.4	47.9	86.23
High Volatile	0.04	6.4	3.2	9.64
Sub-bituminous	1.22	6.2	2.5	9.92
Lignite	0.63	7.3	5.0	12.93
Totals	9.82	50.3	58.6	118.7

**Preliminary Estimate of Measured Coal Resources Including Reassessment of Indicated and Inferred Resources in Western Canada.* B. A. Latour and L. P. Chrismas. Paper 70–58, 1970, Geological Survey of Canada.

The above estimate corresponds approximately in definition with the MINEABLE coal reported by MacKay although it relates to Western Canada only and also shows a much larger tonnage reflecting a greater knowledge gained through new exploration by industry. The 1970 authors did not attempt to go further by allowing for a probable percentage of extraction and showing RECOVERABLE coal as did MacKay.

Briefly, the 1970 report did confirm earlier estimates that Canada possesses very large reserves of coal, measurable in hundreds of years of supply even at greatly increased levels of production. Significantly, also, the report showed that we have firm knowledge about a relatively small percentage of the total as represented by the 9.82 billion tons of MEASURED coal (about 8%). Admittedly, these 9.8 billion tons constitute a very large body of coal. An important observation by the authors was that only 7 per cent of the MEASURED bituminous coal (low, medium and high volatile) can be extracted by surface mining. The bulk must be won by underground methods. This underlines the need for an early and vigorous development of new underground mining methods suitable for the thick, highly inclined and severely faulted coal seams of the bituminous coal fields. For this type of seam, which is characteristic of so much of our more valuable coal reserves, there are very few, if any, successful techniques existing in other coal-producing nations. Consequently, Canada must develop its own techniques.

Although the above geological reporting and coal analyses programs have been of value in defining the locations, magnitude and broad characteristics of Canada's coal resources, there remains a major task of determining how much of this coal can be economically extracted with known technology (RECOVERABLE coal). This latter task requires that the geological and laboratory analysis data should now be supplemented by an assessment based on applied engineering parameters. In this, the objective is to examine these coal resources in terms of established engineering and operating experience to determine just how much of this coal can be economically extracted now, and in the foreseeable future.

The Department of Energy, Mines and Resources has begun this more detailed technical and economic assessment of Canada's coal resources. The first effort is a cooperative program with the Government of Saskatchewan to determine the tonnage of economically recoverable lignite in that province. It is expected that similar joint programs can be started on the sub-bituminous coal of Alberta and for the bituminous fields of Alberta and British Columbia.

Production Capability

Production capability is a function not only of the available coal resources but also the degree of capital risk in exploiting these resources. Very few, if any, mines are opened unless there is reasonably firm assurance about where the coal will be marketed over a period sufficient to amortize the capital invested.

Production capability in Nova Scotia will likely remain static over the next 15 to 20 years. For New Brunswick, coal production will probably cease after 1980. This overall Maritime situation reflects the scarcity of economically available coal resources.

Substantial increases in production capability are expected to continue in Western Canada where coal resources are large and where mining and marketing conditions are such that viable coal mining enterprises can be established.

Dealing jointly with the prairie mines of Saskatchewan and Alberta, which produce lignite and sub-bituminous coals from surface mining operations, these already possess a substantial production capability and have the potential for a strong expansion. This potential arises not only from the large reserves of economically available coal but also from the relatively good and reasonably predictable mining conditions. Productivities are high, being in the range of 40 to 50 tons per man shift. The operations are almost totally mechanized and, because of the relatively shallow and unconsolidated nature of the strata overlying the coal seams, the mechanical mining equipment employed is largely of standardized, proven design. Under these mining conditions, an expansion of production capability does not present unusual problems. The main market is the growing electric utility industry of the Prairie Provinces which consumed approximately 8 million tons of lignite and sub-bituminous coals in 1972. The prediction is that this market will grow to about 14 million tons per annum in about ten years. No unusual problems are anticipated in reaching this higher level. It may also be noted that, when and as gasification of coal becomes economically attractive in Canada, it will likely be based on these lignite and sub-bituminous coals mainly because the process requires low cost coal.

Of equal significance are the larger reserves of sub-bituminous coal recoverable by underground mining. Favourable mining conditions will permit the use of highly productive mining equipment which will result in low operating costs.

Farther westward, in the mountain coal fields of Alberta and British Columbia, the production capability of the industry has been substantially enlarged since 1967 and the first growth objective of the operators is to reach the total annual demand of their contracts with Japan. The Japanese contracts now signed call for a total of approximately 14 million short tons per annum and it is hoped that this level can be reached in the mid-1970's. Currently, the total output of these mines is about 10.6 million tons per annum but growth toward the above target is under way.

It is not expected that the capacity of these mountain mines will plateau at the present target of about 14 million tons and the forecast is that they can grow to a capability of 20 and perhaps to 30 million short tons per annum in the 1980's. This could arise not only from increased sales to Japan but also from diversification in other markets including the western United States, South America and Europe. Hopefully, also, some sales can be made in central Canada.

As indicated, existing mines will not be enlarged nor new mines opened unless there are firm assurances of viable markets and it may therefore be expected that growth in production capability will closely parallel the increase in dependable markets.

Competitive Position, Present and Projected

Canadian coal is marketed in competition with foreign coal as well as in competition with oil, natural gas, uranium and hydro power. Its competitive position depends not only on mining conditions and production cost at the mine but, significantly also, on the distances between mine and markets. Being a material

of relatively low unit value, the transportation cost is an important item in its selling price to consumers. This transportation cost factor has much less impact on other energy forms.

Historically, coal has usually been employed close to its point of production thereby minimizing the transport factor. This is particularly true for coals employed for electrical generation or for other steam raising purposes. Coal is at its competitive best in a short-haul situation and a current example is the viable marketing of western lignite and sub-bituminous coals to nearby electric utilities. A striking exception to this historical market pattern applies to the higher quality coals used for metallurgical purposes and where a foreign consumer buys this coal not only from Canada but also from other distant nations. An example is Japan which buys metallurgical coal from Canada, Australia, the United States and Poland. In this situation, the transportation factor is common to all competing suppliers of coal, although in differing amounts.

The transportation cost factor is a major reason why western Canadian coals are not employed in any significant quantities in Ontario and why this important central market has always depended on the nearer coal fields of the eastern United States.

When dealing with the competitive position of coal, it is necessary to do so under the two broad headings of steam coal and metallurgical coal. Coal for steam raising (power) purposes is in direct competition with oil, natural gas, uranium and hydro power. In the Ontario market it also faces severe competition from United States coal. These are formidable competitors and Canadian steam coals have been unable to match them in selling prices except in the significant case of the prairie mines which supply nearby electric power plants. On the other hand, coal use for metallurgical purposes has a special application and has special characteristics not possessed by these competitors (exclusive of foreign metallurgical coals) and its marketing and competitive situation is brighter. Specifically, coal of metallurgical quality with good coking characteristics is needed in large and growing quantities for the reduction of iron ore to metallic iron in the steel making industry. Because of its special metallurgical qualities, this coal commands a higher selling price than steam coal.

Steam Coal. In the Atlantic Provinces the main competition to use of coal for power comes from imported oil which enters these seaboard regions in large quantities and at relatively low prices. Although imported residual oil has risen in price appreciably during the past few years, it is still available at approximately 40 cents per million British Thermal Units which is equivalent to about $10.50 per ton of Nova Scotia coal. This equivalent price is lower than the pithead cost of producing Nova Scotia coal. As well, this cost differential at the coal mine is still further increased by the freight cost of transporting the coal from mine to power plant. This is higher than the cost of moving oil from port to power plant. In New Brunswick, the much smaller and declining industry can continue for about ten years or so to make reasonably viable sales, in the order of about 200,000 tons yearly, to a power plant located within the coal field and somewhat distant from the nearest deepsea port. Discoveries of offshore oil and natural gas in economic quantities would introduce new and very formidable competition for Maritime steam coals.

Steam coal is not competitive in the Province of Quebec which is far from either Canadian or United States coal fields and where imported oil can readily enter via the St. Lawrence River and the Portland pipeline. Quebec also possesses a very substantial hydro power capacity and a beginning has been made in nuclear power.

Ontario is Canada's largest energy market and is being served by native oil and gas as well as by coals imported from the eastern United States. Hydro power is a significant contributor and nuclear power is growing strongly. Canadian steam coal is not competitive, largely because of the distance and freight factors in the case of western coal and, for Maritime coal, this handicap is aggravated by high costs at the mines. However, the costs of all fuels are rising in Ontario and it is not inconceivable that, at some point in future, serious attention will be given to native coals. American steam coals to Ontario, for example, have risen from approximately 35 cents per million Btu's in 1969 to about 41 cents in 1971. Preliminary figures for 1972 indicate that the delivered cost of American steam coal has further risen to about 52 cents per million Btu's. This latter price is getting within range of the deliverable cost in Ontario of the lignite and sub-bituminous coals of Saskatchewan and Alberta. Also becoming of interest is the deposit of lignite at Onakawana south of James Bay. Further rises in the price of American steam coal in Ontario, say to 60 or 65 cents per million Btu's, could make economically attractive the bituminous coals of Alberta and British Columbia. This is dealt with further under the heading of Transportation.

The possible future competitive position of western steam coals in the Ontario market depends not only on further price increases for American coal but also, and more importantly, on the lowering of freight costs through the introduction of unit trains (express coal trains) and possibly coal pipelines. An added attraction is the universally low sulphur content of the western coals, about ½ per cent, which allows them to meet the current regulations regarding atmospheric pollution. The American coals now employed in Ontario have a much higher sulphur content as have most industrial fuel oils.

For the prairie regions of Western Canada, steam coal is strongly competitive as produced by the surface mining of lignite and sub-bituminous coals in Saskatchewan and Alberta. At prices of 10 cents to 15 cents per million Btu's, as delivered to prairie power plants, these coals represent the lowest cost power fuel in North America. At these prices they are much lower than oil or natural gas and it is unlikely that nuclear power will match them in this century. Consequently, this coal market is a strongly competitive and expanding one. Transportation improvement would allow their broader use as far as Ontario.

As yet, coal is not competitive in the power market of British Columbia with the exception of the Hat Creek deposit of lignite. In the future the reject coal from the production of metallurgical coal can be used if a sufficient volume is available. These rejects, which do not meet the stricter metallurgical requirements, could be employed for power generation in suitably designed boiler plants. As a by-product in the production of metallurgical coals, they could be marketed at nearby power plants at prices competitive with other forms of energy. Their availability for this purpose in adequate quantities to support, say, a 500 megawatt power station in the Crows Nest Pass coal field, depends on the expansion of the

metallurgical mines. Such a plant would require about 1.7 million tons per annum. It would also require significant quantities of water and this constitutes a problem in the area immediately adjacent to the mines. Canadian Utilities Limited of Alberta presently operate a power plant adjacent to the metallurgical mines of McIntyre Porcupine Mines Limited in northern Alberta.

Metallurgical Coal. As indicated, better economic possibilities exist for both western and Nova Scotia coals sold for metallurgical purposes.

A major reason for the upsurge in the coal production in Western Canada is the growing demand for the metallurgical coal in the international market. To date, the price setter in this international market has been the United States. Because of sharp rises in labour and material costs during the past three years, aggravated by new legislation respecting safety and environmental matters, the U.S. coal prices have sharply risen. A supplementary reason is that this legislation has restricted the capacity of the American industry to produce enough high quality metallurgical coal for its own needs and for export. Consequently demand is outpacing supply with direct effect on selling prices. Adding to this upward push on demand and prices are the policies of western Europe and Japan for phasing down their non-economic coal industries and increasing their reliance on imported coals.

Technical problems encountered to date, coupled with the low original selling prices to Japan, have prevented most of the western metallurgical coal industry from reaching viability in this international market. Some of the technical problems have been resolved and increases have been negotiated in selling prices. Prospects are brighter but much will depend on the 1973 round of price renegotiations and continuing technical improvement. To place matters in proper international context, it can be added that the chief Canadian competitors, Australia and the United States, also have their own technical and price problems.

Canadian metallurgical coal was exported in 1972 at prices ranging from $12.37 to $16.72 per short ton and averaging about $15.25. This was the price received on board boat, f.o.b. Port of Vancouver. At these prices, Canadian coal is in good export demand but it is believed that an average price of about $18.00 per short ton at port of export would now be more in line with the real value of quality metallurgical coal.

The United States, Australia and Canada are the major sources of metallurgical coal in the international market and they will be called upon to ship increasing tonnages as well as supplying their own internal needs. This international market is a large and growing one, now amounting to about 68 million tons per annum and estimated to grow to 102 million tons by the mid-1970's. The common problem of the supplying countries is to develop adequate mining and transportation capacity for this large global trade and to negotiate prices that will return the investment and provide a reasonable level of profit. The real upper limit on metallurgical coal prices is that set by the coal industries of the coal importing nations of western Europe and Japan. This level is high because of the difficulties and resulting inefficiencies of the native coal industries of these coal importing nations. Sample 1972 pithead prices of metallurgical coal in the main coalfields of western Europe are given below. It should be mentioned that costs and prices at Japanese mines are equally high.

Coal Field	Selling Price*	
Ruhr	$22.90 Canadian per short ton	
Aachen	22.35	"
Saar	23.80	"
Belgium	20.30	"
France-Northern	22.90	"
France-Lorraine	20.95	"

*Official Report of the European Economic Community on the Steel Making and Coal Industries.

In addition, these prices do not constitute the total cost of the metallurgical coal to the overall economy of these nations. If the social costs of the redundant work force are included, the above prices would be higher, in the order of $3.00. At these levels, imported coals from Canada and elsewhere are economically attractive to Europe and Japan.

On the other hand, the internal market in Canada is a more difficult one for western coals to achieve viability in. The large Ontario steel works are supplied with good quality metallurgical coal from eastern American mines which have a rail haul advantage in the order of 1,200 miles. The transportation cost handicap is a formidable one to overcome. The three major Ontario steel works now import about 7.4 million tons of American coal and this demand will likely grow to about 8 million tons in this decade. A capture of some of this new growth, supplemented with a capture of part of the power coal market, could lead to the installation of more efficient bulk transport from west to east. A combined trans-Canada movement of metallurgical and thermal coals in the order of 5 to 10 million tons per annum would warrant the installation of efficient bulk transport comprising unit train-port-Lake boats or, possibly, coal pipelines. Based on preliminary studies conducted by the CPR and CNR, a new bulk transport system could reduce the cost of metallurgical coal as delivered into Ontario by approximately $4.00 per ton. Currently, this is inadequate to meet the stiff competition from the nearer American coking coals, but the competition gap is closing because of strong rises in the delivered cost of the U.S. coal. For example, since 1968 the delivered cost of U.S. metallurgical coals has risen from about $11.60 per ton to approximately $18.70, an increase of over 60 per cent.

Penetration of western Canadian coal into the Ontario market is further restricted because a considerable volume (52%) of the coal imported (7.4 million tons in 1972) comes from mines in the United States owned by the Canadian steel mills. Ownership in some cases consists of equity in return for a percentage of the mine production. Another 27 per cent is covered by long-term contracts.

The metallurgical market for coal is not limited to coals of bituminous rank. Technical processes exist for making similar use of lower rank coals. Such a process employs direct reduction methods of the rotary kiln type and certain form coking processes.

In this overall national and international situation respecting metallurgical coal it would appear that economic possibilities are bright for Western Canada.

It must also be observed that if the Cape Breton Development Corporation is successful in reducing its mining costs and the sulphur content of its coal, it can benefit not only from continued sales to the Sydney steel plant, but also from export sales of this higher revenue metallurgical coal to Europe in quantities up to one million tons per annum. Positive factors in this direction include the high cost at European mines, the strongly rising cost of American coals now going to Europe and the fact that the Port of Sydney is about 800 miles closer to western Europe than is the U.S. coal shipping port of Hampton Roads, Virginia.

Imports

The heavily industrialized parts of central Canada have historically relied on coal imported from the eastern coal fields of the United States. It is expected that this reliance will continue but there is a possibility that it can be modified appreciably by a greater use of Canadian coal. This possibility depends on the success of current efforts to modernize and expand the Canadian coal industry, as well as on the outcome of investigations into new techniques for the efficient bulk transportation of coal to central Canada.

Year-end data for calendar year 1972 show total imports of coal and coke at approximately 19.3 million tons, as follows:

Imports by Provinces, 1972

In short (2000 lb) tons

	Bituminous Coal	*Anthracite*	*Briquettes*	*Coke*
Newfoundland	1,285	0	0	0
Nova Scotia	109,989	0	0	146,015
New Brunswick	650	299	0	0
Quebec	324,478	345,155	0	233,345
Ontario	17,667,666	100,438	2,561	378,432
Manitoba	8,912	0	3,804	14,422
Saskatchewan	0	30	2,523	2,125
Alberta	0	0	0	0
British Columbia	84	48	1,847	2,359
Canada total	18,112,064	445,970	10,735	776,698

As will be noted, the bulk of the imports are to Ontario, in the form of bituminous coal. Further to this concentration, most of this bituminous coal is used by two industries; by Ontario Hydro for electrical generation, and by the three steel making companies of Ontario. Ontario Hydro consumed about 8.4 million tons in 1972 and the steel plants approximately 6 million tons.

The probability of increased imports to Canada in future years depends largely on the coal requirements of these two Ontario industries. All other coal markets in Ontario will continue to drop and the same declining pattern applies to most of the imports to other provinces.

In Ontario, the probability is that the steel industry will maintain an increasing demand of about 4 per cent per annum and its needs will likely rise from the 1972 level of approximately 6 million tons to about 8 million tons of metallurgical coal in 1980.

The future prospects for steam coal are more difficult to forecast but a number of influencing factors could result in a levelling off in coal used for electric power generation in Ontario. These factors include:

Strongly rising prices of imported steam coal. Since 1967, prices have risen by about 40 per cent.

A higher sulphur content in imported coal than desirable under environmental control regulations.

A larger use of natural gas or residual oil in place of coal.

The increasing use of nuclear power.

The probability for 1980 is that the use of imported coal for electrical generation will remain at approximately present levels and will be employed in existing coal-fired plants. Also, that the increase in imports for metallurgical use will be offset by decreases in other Ontario industries and in other provinces. The net effect is that total coal imports of all types of coal will likely show no increase during the rest of this decade and plateau in the range of 18 million to 19 million tons by 1980.

As indicated however, the prospects for steam (power) coal in Ontario are difficult to define over the next ten to twenty years. This is because of a number of other factors, actual or potential, that could materially alter the choice of fuels in Ontario and lead to a greater use of steam coal. They are:

The current use of natural gas is based largely on its environmental acceptance relative to imported coals.

Natural gas will likely increase substantially in price. Oil prices are also rising.

An adequate reduction in freight rates through use of unit trains could deliver low sulphur western coal to Ontario at prices in the order of 60 cents per million Btu's for lignite, 55 cents for sub-bituminous and 66 cents for bituminous. For comparison the current costs of power fuels in Ontario are 52 cents per million Btu's for U.S. coal, 55 cents for natural gas and about 60 cents for No. 6 oil.

If the nuclear power program does not proceed at the pace expected, the shortfall in electrical energy must be made good by other energy sources.

In view of these considerations the possibility exists for increased use of steam coal in Ontario. Should this situation develop, it is probable that it would prove economic to employ the low sulphur western coals instead of high sulphur imports. This would eliminate the heavy capital cost of installing sulphur removal equipment in the boiler plants to meet environmental standards.

Canada imposes no duty or restrictions on imported coal. At present, very little Canadian coal is marketed in Ontario and the imposition of duties or restrictions would penalize the coal-consuming industries of Ontario and Quebec without any appreciable off-setting benefits to the Canadian coal industry. The present federal government approach is to promote technical/economic studies aimed at improving the production and transportation of Canadian coals thereby enhancing their marketability in full competition with imported coals. This is further dealt with under the heading Transportation.

Investigations of this nature have a strong potential for generating broadly ranging benefits to the Canadian economy because a cross-country traffic in coal, in the order of 5 to 10 million tons per annum, would directly benefit not only the producers and consumers but also the railways, the Port of Thunder Bay and shipping industry on the Great Lakes. It would also contribute to a national self-sufficiency in energy.

EXPORTS

Canadian exports of coal have risen over the past four years from 1.37 million short tons in 1969 to 9.4 million tons in 1972, as follows:

EXPORTS

	*1972**	*1969*
To Japan	9,298,300	1,156,000
To United States	12,200	216,000
To Europe	38,800	6,000
To South America	71,600	—
	9,420,900	1,378,000

*Year-end data, subject to some revision.

As shown, the bulk of the exports go to Japan and it is expected that exports to that country will grow from the 1972 level of 9.3 million short tons to approximately 14 million tons in the mid-1970's. This is about the level of annual shipments under contracts signed by six Canadian coal producers with Japanese buyers.

Further contracts with Japan will likely be signed and, in addition, it is expected that greater market diversification will be established through contracts in other countries including Europe and South America. A reasonable expectation is that total exports will grow to about 20 million tons per annum by 1980 and to 25 million tons during the 1980's. At current selling prices, on board boat at port of exit, a 20 million ton export has a value of approximately $300 million per annum.

This rising volume of Canada's exports is part of a global increase in the international marketing of metallurgical quality coal. This global increase arises from two main reasons. One is the growing inability of many heavily industrialized

nations, including those of western Europe and Japan, to produce their own metallurgical coal at competitive prices. The ancient coal industries of these countries are beset with difficult mining conditions, as well as very heavy "social" costs rising from their attempts to reduce their non-economic coal production. For economic reasons, these industrialized nations are importing an increasing percentage of their coal needs mainly from the United States, Australia, Poland and Canada.

A second supporting reason for this growing international market is the recent development of more efficient and less costly means for the bulk transport of coal. This includes the appearance of cargo boats of 100,000 DWT and larger, together with the introduction of specially-designed unit trains for overland transport and high capacity dock facilities.

This global trade in coal is forecasted* to grow to about 100 million metric tons annually by 1975 (123 million short tons). This represents the import needs of western Europe, South America and Japan. As already indicated, it is expected that Canada's share of this market will be in the order of 20 million annually by the end of this decade and to 25 million tons in the 1980's. This expectation will call for a large expansion of the Canadian coal mining industry, together with large additions to railway systems and ports. It will require a much greater work force. Undoubtedly, these enlargements will be of very material regional benefit especially in Alberta and British Columbia, but their orderly attainment needs programming on a national scale in cooperation with the provinces and industry.

Relative to the United States and Australia, Canada's coal deposits have more difficult mining conditions and are a greater distance from its ports. The Australian mines average 100-200 miles to seaport, and the United States mines about 400, compared with the 700 miles between the western Canadian mines and Vancouver. The Canadian coal seams are more steeply inclined and faulted. These relatively more adverse conditions will place Canadian coals at a cost disadvantage in comparison with those of the United States and Australia. The reduction of these mining and transportation problems is therefore fundamental to Canada's continuing participation in the international market.

An associated benefit of this participation in the global market is that the coal industry of Canada can thereby grow to the dimensions required for supplying Canada's own coal needs at competitive prices. Currently, Canada's own needs are inadequate for building the coal industry to an efficient size. It is clear that the currently small home market for metallurgical coal must be supplemented with a substantial export market if the bituminous coal industry is to reach a size necessary for best operational and cost performance.

Demand for Coal

The marketing pattern has radically changed since World War II, from one of supplying a wide variety of customers comprising a mix of small and large consumers, to one of supplying a few but individually large industries. Specifically, the coal market is now largely concentrated on the electric utility industry and the metallurgical industry. All other markets have disappeared during the past two

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* Organization for Economic Co-operation and Development (OECD), 1972.

decades or are continuing to decline. This change is not entirely a depressing one because the present marketing pattern is basically sound and has excellent scope for employing coal resources to good national advantage.

The present marketing pattern is as follows:

Market	*Per cent of Market*
Thermal Electric Industry	49.0
Metallurgical Industry	19.0
General Industry	4.0
Space Heating	1.5
Export Market	25.4
Miscellaneous	1.1
	100.0

The marketing bias toward thermal electric, metallurgical and export markets can be expected to increase and future markets will be based exclusively or nearly so on these three growing outlets for coal.

The supply of coal, which includes imported coal, will continue to rise and is expected to increase from the present level of 39.9 million tons per annum to about 55 million tons by 1980. This growing supply, necessary for meeting the increasing demand, will be met by a greater production of native coal supplemented by imports from the United States, as follows:

	Supply (Actual) 1972	*Supply (Projected) 1980*
Canadian Coal Production	20.6	37 million tons
Imports from U.S.A.*	19.3	18 million tons
Total coal and coke supply	39.9	55 million tons

*Includes all coals and coke.

The forecasted 37 million tons of Canadian coal will probably be marketed as follows in 1980:

To electric utilities in Alberta and Saskatchewan	14.5 million tons
To electric utilities in New Brunswick	0.2 million tons
To electric utilities in Nova Scotia	0.7 million tons
By metallurgical sales of Nova Scotia coal	1.3 million tons
By exports of Alberta and British Columbia coal	20.0 million tons
Total	36.7 million tons

This 36.7 million tons estimate for markets (and Production) may be increased by 5 million tons if the western Canadian coals are successful in capturing some of the Ontario market on a competitive basis from the imported American coals. The estimate may be even further increased by several million tons if the reject coal from the western metallurgical mines is employed in electric utility plants in Western Canada. This latter possibility depends on decisions by the electric power authorities of Alberta and British Columbia. One power plant, at Grande Cache, Alberta, is now using such coal from the nearby mine of McIntyre Porcupine Mines Ltd.

The imports from the United States are shown at 18 million tons for 1980, in view of the possibility that coal for electrical generation will likely remain at the present level and that the increase in volume expected for metallurgical coal will be offset by decreases in other Ontario markets and in other provinces.

The foregoing analysis is related to the marketing pattern and coal supply as of 1972 and as projected to 1980. For the period beyond 1980 and to the year 2000, a reasonable expectation is for a stronger demand on Canadian coal resources for power generation in Alberta and Saskatchewan and for benefitting from an attractive export market in metallurgical coal. Conceivably, the coal supply in Canada could rise to about 120 million tons per annum by the year 2000. As follows:

SUPPLY PROJECTED—YEAR 2000

Electrical generation	79 million tons
Metallurgical	16 million tons
Export	25 million tons
Total supply	120 million tons

The 79 million tons of coal projected for electrical generation is conservative and will increase if the Alberta government adopts the recommendation made by their Energy Resources Conservation Board, namely, to fuel future electrical generation plants with coal rather than gas. The 16 million tons of coal projected for metallurgical use is based on coals of coking quality. Advances in technology may permit the use of lower rank coals than are currently being used. Hence prairie coal resources may be an economical substitute.

The above table of estimates doesn't include the possibility of converting coal into liquid and gaseous fuels. The techniques for doing so, particularly gasification, are under vigorous development in the United States, where the current energy situation makes the subject of more imminent importance than in Canada. The successful evolution of an economic conversion process could be of future commercial interest in Canada and, if so, would result in another large demand on our coal resources.

The known reserves of coal are adequate for meeting these higher levels of coal marketing and supply.

Transportation

Broadly, the need for improvements in the bulk transportation of coal is of more immediate concern to Canada's own internal needs for coal than it is to our export trade in that resource material. Currently, the bulk of Canada's coal exports are proceeding to the coastal ports of British Columbia via a new and modern system of unit trains which employ specialized rolling stock. The B.C. ports are large, modern in design and highly efficient in operation. Consequently, the flow of coal to the Pacific coast for export is proceeding with acceptable efficiency and at reasonable cost.

On the other hand, the transportation of coal to consumers within Canada is nowhere near as modern and efficient. For example, the haulage of coal from Western Canada to central Canada is still being affected by a mixed-train system at relatively high cost. In addition, there are no adequate facilities for transshipping western coal from rail to boat at Thunder Bay or for shipping coal in adequate volumes down the Great Lakes. With respect to the Maritimes, coal is still being handled by a mixed-train system. The proximity of the major mines in Nova Scotia to tidewater and the existence of a fairly new coal dock in Sydney Harbour will prove beneficial if substantial water shipments are resumed.

As opposed to these inadequacies in moving Canadian coal across Canada, there exists a very efficient land/water system for transporting coal northward from the United States coal fields into the major Canadian energy markets of southern Ontario. This transport situation is one reason why central Canada is such a large importer of United States coals and why the Canadian coal industry is not competitive in that large central market.

An effective system should be developed for the eastward haul of western coal to the central provinces if Canada is to achieve a greater self-sufficiency in coal supply. An investigation has been made of the technical and economic possibilities of such a transport system.* This study was based on the concept of a unit train system between the western mines and Lake Superior, with the installation of large modern dock facilities at Thunder Bay and the procurement of large size ships (27,000 dwt—50,000 dwt) or tug-barge combinations for the lake haul. The report indicated that such a system was technically feasible and could result in a substantial lowering of transportation costs. The following table shows the estimated costs for moving western bituminous coal which requires a freight haul of about 1,500 miles, sub-bituminous coal at 1,150 miles and lignite coal for Saskatchewan at 700 miles to Thunder Bay.

	Bituminous	*Sub-bituminous*	*Lignite*
Rail freight	$5.95	$5.45	$3.45
Port charges	1.00	1.00	1.00
Water haul	2.00	2.00	2.00
Total Transport	$8.95	$8.45	$6.45

*"Coal Market Survey—Great Lakes Area" by Canadian Pacific and Canadian National Railways, November, 1971.

These transportation costs average about $4.00 per ton less than current costs and this reduction could materially improve the competitive position of western coals in the Ontario market.

Supplementing this potential benefit is the fact that American coals have strongly risen in price which serves to further narrow the adverse competition gap between native and foreign coals. By employing the above estimated transportation costs, the possible delivered cost of Canadian coal would be as follows

(The current cost of the American coal is also shown for comparison):

For Metallurgical Coal

	Price at Mine	*Estimated Transport*	*Delivered Cost*
Canadian Bituminous (possible)	$10.66	$8.95*	$19.61
American Bituminous (actual)	—	—	$18.71

* A railway estimate of 1971 for a movement of 5 million or more tons per annum.

In this table, the price at the mine for Canadian bituminous coal is the weighted average received from the 1972 exports to Japan. The delivered cost shown for American bituminous is the average cost (price paid) in Ontario in calendar year 1972. In view of the strongly rising cost of the American coal, which has risen about 60 per cent since 1968, the above table indicates that, with a new transport system, the western metallurgical coal could compete in the Ontario metallurgical market in the reasonably near future.

The above table shows merely the possible delivered cost of Canadian metallurgical coal. What the Ontario steel industries are prepared to pay depends also on the comparative metallurgical characteristics of the Canadian and American coals such as sulphur and ash content and coking characteristics. In this comparison, the Canadian coals should fare satisfactorily. It will be lower than much of the imported coal in sulphur which should command a price premium and, by the application of current advances in technology, the approximately 2.5 per cent ash disadvantage can be reduced by half.

For coal employed for steam raising purposes, such as electric generation, the possible competitive position of Canadian coals, with a new freight system is approximately as follows. This table shows the two types of western coals now being produced for steam raising purposes, namely, sub-bituminous and lignite coals.

For Steam Coals

	Price at Mine	*Transport*	*Delivered Cost*	*Cost per Million Btu*
Canadian Sub-bituminous	$2.50	$8.45	$10.95	58 cents
Canadian Lignite	$2.50	$6.45	$8.95	64 cents
American Bituminous	—	—	$13.40	52 cents

The last column showing cost in cents per million British Thermal Units is a valid means for comparing the relative cost values of these fuels of differing heat content per unit of bulk.

The above table does not show a probable delivered cost in Ontario of the higher rank bituminous coal of Western Canada. This is because such coal is not now being produced for the steam coal market. However, a reasonable estimate is that western bituminous could be delivered into Ontario for 65 cents to 70 cents per million Btu's.

Not shown in the above table is a premium value that would likely accrue to the Canadian coal because of its much lower sulphur content (about ½ per cent) as compared with the American steam coal of 2 to 3 per cent. In the CPR/CNR report of November, 1971, this premium was estimated at 8 cents per million Btu for Canadian bituminous coal. Although it would be somewhat lower for sub-bituminous and lignite coals, nevertheless the application of this premium to the above table would bring Canadian coals close to the present American cost. This low sulphur premium has not been included in the above table.

It should be noted however that the boiler plants of Ontario Hydro are designed to burn bituminous coals and if the lower rank lignites or sub-bituminous coals are employed, this would reduce boiler rating. This in turn would reduce the rated generating capacity of the power plants.

In summary, the rising price of U.S. coal in the Ontario market, the introduction of a modern coal transport system between Western Canada and the Great Lakes could materially assist Canadian coal to become competitive in this central market and make the transport system viable.

A promising method for economically transporting coal in large quantities and over long distances is the pipelining of coal cross-country. This method is now being successfully applied between a coal mine in Arizona and an electric utility plant in Nevada. This coal pipeline transports about 5 million tons of coal per year, through an 18-inch diameter pipe over a distance of 270 miles. There would be no insurmountable technical problems over greater distances. This application uses a slurry of coal mixed with water but another possibility that has received study is a coal/oil slurry.

In Canada, the technical and economic factors related to pipelining coal have received the serious attention of Shell Canada Ltd. and Canadian Pacific. Problems affecting a Canadian use of the method are in process of solution, including the effect of prolonged water immersion on the metallurgical qualities of coal and the separation and disposal of the liquid component at the delivery point.

Control of the Canadian Coal Industry

Jurisdiction over the rights to coal reserves in Canada lies almost entirely with provincial governments but the federal government does have jurisdiction over the coal mining rights in the Yukon and Northwest Territories, in National Parks, on Indian Reserves and in the Dominion Coal Blocks which are located in the Crowsnest Pass coal field of eastern British Columbia. However, all of these areas of federal control are inactive with respect to coal mining. Briefly, the governments of the coal-bearing provinces exercise almost exclusive authority over the issuing

of mining rights to industry, as well as over matters related to the safe operation of the mines and to conservation of this resource.

Operationally, ownership of the Canadian coal industry is becoming concentrated in relatively few hands and there is a substantial degree of control by United States interest. This pattern of ownership applies to Western Canada, where the industry is experiencing its greatest expansion, but not to the Maritime coal industry which is under federal/provincial management. With respect to Western Canada, seven companies produce about 90 per cent of the coal production and three of these are subsidiaries of U.S. corporations.

Formerly, the industry of Western Canada included many small operators based on localized coal sales, but technological changes have drastically changed this marketing pattern to one where the market is concentrated on a few but individually massive consumers, principally the metallurgical industry and the thermal-electric power plants. These modern markets are not only large but are highly competitive and, in practice, they can be economically serviced only by the larger producers which can generate the annual volume of coal production required to achieve lowest unit costs.

In general, only the larger companies can marshal the capital, quality of management and marketing expertise required in the modern coal market. This is the basic industrial factor that governs the pattern of control in the coal industry of Western Canada.

This concentration of industrial control and corporate decision-making is not, per se, inimical to Canadian interests. It does, however, increase the hazard of such control falling under foreign domination whose objectives could, conceivably, be detrimental to Canada's interests. For example, a foreign corporation controlling coal mines both in Canada and elsewhere might find it more profitable, at times, to shut down or restrict its Canadian mines and to direct its capital and coal markets to its non-Canadian operations. Briefly, such Canadian coal mines might degenerate into standby operations.

With respect to Canadian capital the amount required for developing a major mine producing, say, three million tons per annum, is in the order of $90 million. This sum is not beyond the capacity of the Canadian investment public. However, coal has yet to regain public recognition and acceptance as an investment medium and would probably be regarded as an unduly high risk unless inducements were offered for accelerated return of capital and a favourable tax treatment.

Factors contributing in a very material way to this concept of risk are the technical unknowns related to the economic extraction and preparation of a large percentage of Canada's coal reserves. A comprehensive program of research and development would be effective in reducing these problems to manageable proportions and help in establishing investor confidence.

With respect to diversification of foreign ownership it would be beneficial to promote participation from nations having primarily a consumer's interest in Canada's coal reserves, as a balancing influence on other nations with a producer's interest. For example, Japan is a massive buyer of Canadian coal and it is conceivable that a Japanese ownership in a Canadian mine would help stabilize its Japanese market. The same concept could apply to European ownership.

Environmental Considerations

The use of coal resources affects the environment at point of production and at point of consumption. The former is commonly located in sparsely populated regions but the latter is often near industrialized and high density population centres.

At the coal mines, the chief effect is disturbance of the land, particularly when surface mining is employed. This method is extensively used at the mountain mines of British Columbia and Alberta and also at the prairie mines of Alberta and Saskatchewan. The small New Brunswick operations also employ this method. The effect of underground mining on the surface topography is very substantially less and makes itself evident through a more localized subsidence of the land surface if underground coal extraction is extensive and conducted at fairly shallow depths. Very little of this type of mining is conducted in Western Canada although it will likely be more widely employed in the next ten to twenty years. It is the only method employed in Nova Scotia where, however, the mines are deep and extend beneath the ocean floor. As such, current mining operations do not disturb the land surface, although there is a residual and decreasing problem of subsidence caused by past mining operations underland.

The restoration of disturbed land following surface mining operations is receiving considerable attention both in Canada and elsewhere. Useful techniques have been developed for restoring the surface to a useful condition.

On the Canadian prairies, the reclamation operations can be conducted at reasonable cost. At a typical prairie strip mine, the cost of regrading and re-vegetation runs from $300 per acre when the overburden is coarse material to $600 per acre when the overburden is clay requiring a rehandling of the surface soil. At these costs, and assuming an average recovery of 15,000 tons of coal per acre, the cost of reclamation would add about two per cent to the selling price. This prairie coal, comprising lignite and sub-bituminous coals, is sold mainly to the local electric utilities and reclamation of the land will not significantly increase the cost of electricity.

Land reclamation at the mountain strip mines of British Columbia and Alberta is a more costly undertaking because of the greater and more abrupt variations in the mountain topography, as compared with prairie conditions, and because of the much greater thickness of the coal seams and their highly inclined nature. Much more is needed in the way of siltation dams and tailing ponds to prevent pollution of streams. More effort and expense are also required in preparing suitable areas for disposal of dry wastes and, very importantly, for the hauling and compacting of massive volumes of waste rock into permanently stable and environmentally acceptable storage piles. Conservatively, these requirements can add about 15 per cent to the costs of a typical mine. For example, the required costs would total about $90 million over a 15 year operational period, for a mine producing, say, 3 million tons of coal per annum.

Other related environmental problems at the mines include the emission of acidic mine waters, the siltation of streams by fine sized particles of coal and rock, and airborne dusts. Western Canada is fortunate in that its coal is low in sulphur content and hence acidity of mine waters is minimum. The coals of

Nova Scotia and New Brunswick are higher in sulphur content and mine waters can be appreciably acidic. The problem of siltation requires, as indicated, the use of adequate settling ponds. The new coal preparation plants in Western Canada have been designed to reduce airborne dusts which is particularly important when handling the friable coals of the western mountain mines.

The cross-country transport of coal in open-top railway cars can result in airborne dusts. The same applies, through wind action, on large stockpiles at the shipping docks. The use of covers and plastic sprays on exposed coal surfaces are being explored for effectiveness.

Coal is now almost entirely consumed by industry and at the plants of these large consumers problems arise from the emission of solid particulates and gases from boiler stacks and from the dusts and gases produced in the coke oven plants of the metallurgical industry. The emission of solid particulates from the stacks of boiler plants, notably those of the electric power utilities, is being very satisfactorily reduced by electrostatic precipitators which remove over 99 per cent of stack dusts. Less success has been achieved to date in the removal of sulphur dioxide and nitrogen gases. At the steel making plants, very considerable expenditures have been made to reduce dusts and gases at existing coke ovens and new ovens are designed with built-in features for suppression.

The Sydney Coal Field

The coal field at Sydney, N.S. is the only major body of Canadian coal reserves east of Ontario and consequently it warrants consideration in national energy planning, especially for the Maritime Provinces.

It has been extensively worked and, because of its seaboard location, the present mining operations are being conducted in sub-sea workings that lie at the substantial distances of three to four miles from the coast line. As well, the gradual progression of these mine workings as they follow the inclined seams below the ocean means that coal mining is now being conducted at the substantial depth of approximately 2,500 feet below the sea floor. The cost of producing coal is high and there is formidable competition from imported oil which readily enters the Atlantic Provinces in large volumes at competitively low prices.

The net result has been a steadily worsening economic position for these large sub-sea mines and their dependent communities. This led to notification by the private operators of an intent to cease operations and subsequently to the take-over of these Sydney collieries in 1968 by a federal Crown agency, the Cape Breton Development Corporation.

Prior to this take-over, the federal government had a long history of financial assistance to these Sydney operations, extending back 40 years to 1928. This assistance remained relatively modest until the mid-1950's, but then escalated, particularly during the 1960's, because of rising mine costs and the appearance in that decade of foreign oil in large quantities. Over the 40-year period, total subvention for the marketing of coal from these mines amounted to $237,556,780 on a subvented volume of 58,700,956 tons, averaging $4.05 per ton. Of this total the Government of Nova Scotia contributed about $2.5 million. By including such additional forms of aid such as payments made under the Canadian Coal Equality

Act and the Atlantic Provinces Power Development Act, together with wartime expenditures on grants and subsidies during 1940-45, the total assistance is in the order of $300 million. This does not include the benefits accruing under the Maritime Freight Rates Act or from federal support of research and development related to Canada's coal resources.

The Cape Breton Development Corporation was established in 1968 with the broad objectives of phasing down the coal mining operations and, concurrently, of promoting the introduction of other forms of industry for re-structuring and broadening the economic base for Cape Breton Island. Its duties and responsibilities are defined in the Cape Breton Development Corporation Act (Chapter 16 Elizabeth II).

The powers invested in the Corporation are broad. It has expropriated the coal mining and related assets of the private operators and is empowered to rehabilitate, improve, open, operate and maintain any coal mines or related fixtures. It can enter into contracts related to the production, marketing and shipping of coal acquired by or produced by DEVCO.

With respect to the development of other industries, it has authority to lend money, to guarantee loans, and make financial grants to any company or person likely to make a substantial contribution to the industrial development of Cape Breton Island. It can also invest in the shares or securities of such company or person. It can purchase, manage, develop and sell lands or interests on Cape Breton Island and accept mortgages related to such disposals.

Since its inception, the Corporation has experienced difficulties in attracting viable new industries and consequently it has not been found possible to phase down coal operations at the rate originally envisaged. In this situation, a basic need has been to maintain the local economy at reasonably acceptable levels and, to do so, much continuing reliance has had to be placed on the coal operations.

Reductions have been made since 1968 in colliery employment and in the level of coal production. Employment in DEVCO's Coal Division has declined form 6,058 in 1968 to under 4,000 at end of 1972 mainly through policies of limited hirings and of early retirements. During the same period, coal production has been decreased from 2.7 million tons in calendar 1968 to approximately 1.3 million tons in calendar 1972.

The Coal Division of DEVCO has incurred the following annual operating losses and these losses do not include provision for depreciation of assets:

For 1968 (9 months)—$17,100,169 (1st year of DEVCO control)

For 1969 (12 months)—$21,935,092

For 1970 (12 months)—$25,778,377

For 1971 (12 months)—$31,600,000 (estimated)

For 1972 (12 months)—$32,600,000 (preliminary figure)

These operating losses are covered by allocations from the Consolidated Revenue Fund of the federal government.

It is apparent because of the difficulty in attracting new industries, that the Corporation must continue to rely for an indefinite period on coal mining to

support the local economy. More hopefully, recent developments related principally to an increased demand and prices for coal lend credence to new speculation about the economic possibilities for coal mining. These market developments are largely related to rising prices for metallurgical coal. Such market developments and the operational planning of current management offer reasonable promise for materially reducing the annual losses.

Currently, DEVCO still maintains 3 of the 4 mines that were taken over from the private operator in 1968, namely: Number 12 Colliery in New Waterford; Number 26 Colliery in Glace Bay; and the Princess Colliery in Sydney Mines. The Number 20 Colliery was closed in 1972. In addition to the above existing collieries, DEVCO has opened a new Lingan Mine located between Glace Bay and New Waterford.

One of DEVCO's problems has been an inability to close the poorer collieries, and thus concentrate its efforts on the better ones, without causing substantial disruptions in local employment. For example, Number 12 and Princess Collieries should rationally be closed and the coal production concentrated in Number 26 Colliery and the new Lingan Mine. This could be achieved progressively over several years in tune with improvements made in Number 26 and the further development of Lingan. Additional possibilities deserving attention include the development of a new mine in the Donkin district of the Sydney coal field, together with one or more small, new collieries in other favourable locations. Briefly, concentration of effort in the best locations now remaining in this extensively-worked coal field offers best promise for materially improving productivity and decreasing the losses of DEVCO's Coal Division.

Reduction in coal production without a parallel reduction in the number of producing units (collieries) only results in each unit operating much below its optimum level of coal production. This leads to lower productivity, rising operating costs and rising losses. The solution of concentrating operations is technically obvious but is socially difficult because it involves reduction and re-deployment of the work force which still constitutes a major element in the economic life of the region. In the re-directing of this industry, technical expertise must be supplemented with a clear understanding of the significant social forces involved. As indicated, the promotion of alternative industries has been a disappointing experience but DEVCO is not unique in this respect because quite similar problems have been encountered in regional development programs elsewhere in Canada and in other nations. Adequate growth time is of the essence in industrial promotion for the careful evaluation of proposed undertakings and for the control of new industries during their first few critical years. It is believed that DEVCO can obtain the required growth time if it can progressively recast its coal mining operations so that these can carry a major portion of the employment burden, at a more acceptable public cost, during the intervening years.

The achievement of these coal mining objectives will be markedly enhanced by marketing efforts aimed at maximizing the selling price of the coal. DEVCO has already made progress in this direction by obtaining increases in pithead prices from $7.09 per ton in 1968 to $11.50 in 1972. Further rises are anticipated. A substantial reason for this change in average receipt has been a progressive redirection of coal sales to the higher revenue metallurgical market with a con-

current reduction in the percentage of the total output sold in the lower value thermal electric market. Sales to the metallurgical market constituted only 6 per cent of coal disposals in 1968 but increased to 24 per cent in 1972. Much of this relates to the recapture of the market at the Sydney steel plant from American coals.

A prime requirement for maximizing market prices is to upgrade the Sydney coal by reducing its sulphur content. This is essential not only for the metallurgical market but also, for environmental reasons, for the electric utility and other steam coal markets. The Sydney coal is of excellent metallurgical and steam coal quality, with low ash content, but the sulphur content is generally in excess of current and future market requirements. The Department of Energy, Mines and Resources is cooperating with DEVCO in developing a method for reducing the sulphur component to commercially acceptable levels. It is expected that this method can be incorporated in the design of the new coal preparation plant being planned for by DEVCO.

Dominion Government Coal Blocks

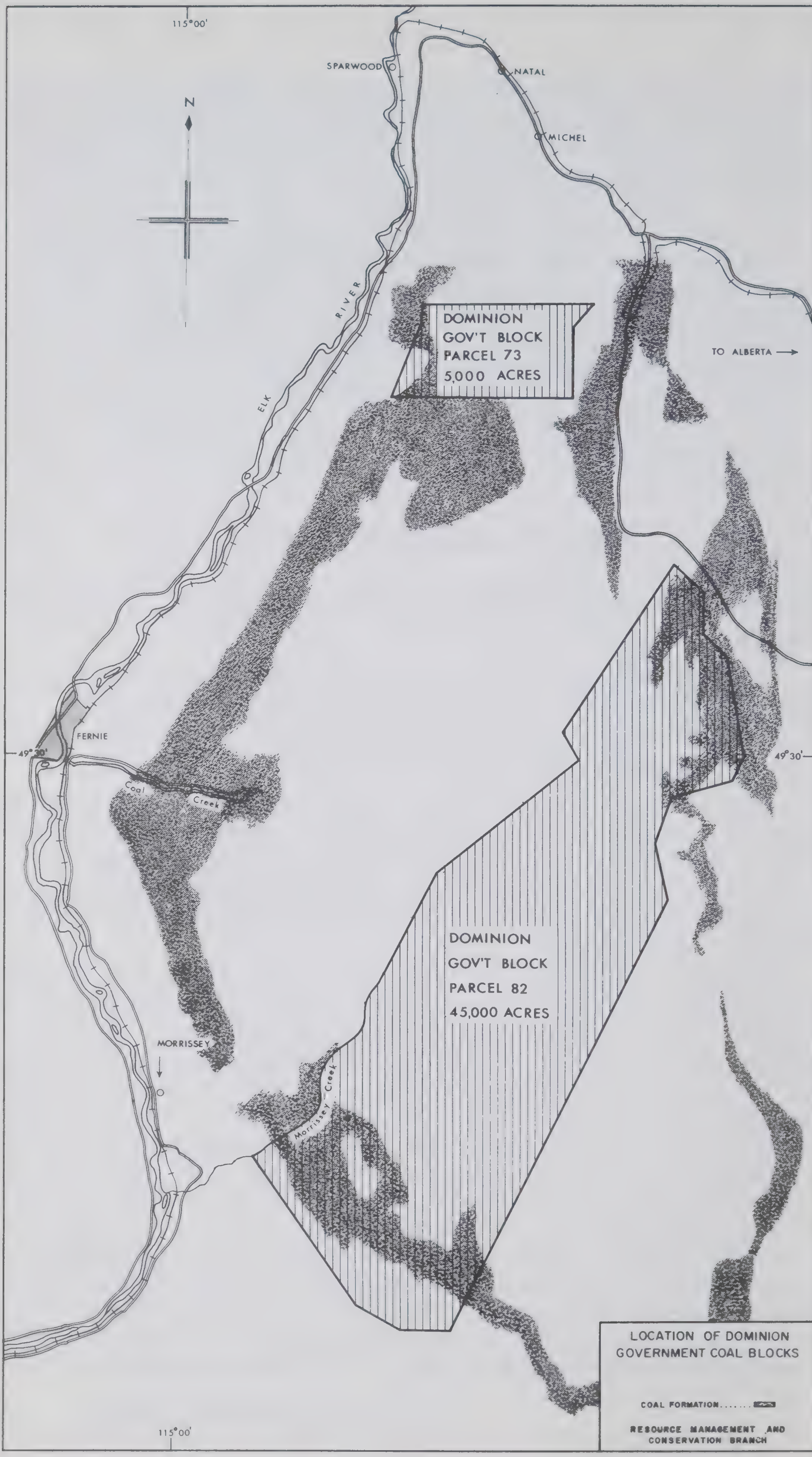
The Government of Canada holds the mineral and surface rights on two tracts of land in the Crowsnest Pass Coalfield of the Kootenay District in British Columbia.

These two tracts comprise Parcel 73 consisting of 5,000 acres and Parcel 82 of 45,000 acres for a total of 50,000 acres of coal-bearing lands. (See map.)

The Government of Canada holds these rights under the terms of the Crow's Nest Pass Act which was assented to on June 29, 1897.

Historical Background. In 1888 British Columbia chartered the Crow's Nest & Kootenay Lake Railway Company (subsequently renamed the British Columbia Southern Railway Company) to construct a railway line from the Alberta border across British Columbia to Nelson. To promote this, British Columbia passed its Railway Subsidy Act in 1890 providing for a land grant of 20,000 acres for each mile of railway constructed.

On June 29, 1897, the Crow's Nest Pass Act was assented to. Under this Act the Canadian Pacific Railway Company was required to carry certain products (including coal and grain) at the rates fixed in the Agreement, to grant certain running rights on its railway lines subject to control of the Governor-in-Council, and to convey to the federal government a portion up to the extent of 50,000 acres of any lands granted as a subsidy for the construction of the railway by the British Columbia government, this portion to consist of lands which in the opinion of the Director of Geological Survey of Canada were coal-bearing lands. In return, the railway received a federal subsidy of $11,000 per mile, but not exceeding $3,630,000 to assist in the construction of the Crow's Nest Pass Line from Lethbridge, Alberta to Nelson, British Columbia. On July 30, 1897, a tri-partite Agreement was entered into between the Canadian Pacific Railway, British Columbia Southern Railway (which was fully purchased by the CPR in August, 1897) and Kootenay Coal Company (later renamed Crow's Nest Pass Coal Company) under which British Columbia Southern Railway undertook to build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LOCATION OF DOMINION
GOVERNMENT COAL BLOCKS
COAL FORMATION.......
RESOURCE MANAGEMENT AND
CONSERVATION BRANCH

the railway and to convey to the Government of Canada 50,000 acres of land from the land to be received from British Columbia under the 1890 Railway Subsidy Act.

On September 6, 1897, the CPR entered into the Agreement with Canada as required by the Crow's Nest Pass Act thereby assuring the subsidy of $11,000 per mile.

On August 18, 1899, the Lieutenant Governor-in-Council of British Columbia, by Order-in-Council No. 539, granted to the British Columbia Southern Railway Company an extensive tract of land comprising about 610,000 acres in the Kootenay District. Conveyance of this land was affected by Crown Grants 1165-109 and 1166-109 dated August 18, 1899, which reserved all minerals other than coal to British Columbia.

These lands were examined by representatives of the federal government, and 50,000 acres of coal-bearing lands were selected pursuant to the terms of the Crow's Nest Pass Act. This selection was confirmed by Order-in-Council P.C. 664 dated May 19, 1902, and a perimeter survey was carried out between 1902 and 1905. Title to the surface and coal rights was duly conveyed to the Crown in right of Canada from the British Columbia Southern Railway Company under a deed dated September 14, 1905, and a Certificate of Indefeasible Title 19-1 dated November 27, 1905, was issued to His Majesty in right of Canada in respect thereof by the District Registrar of the Land Registry Office in Nelson, B.C.

The Crow's Nest Pass Act has primarily to do with railway transport considerations, particularly as related to movement of grains. The coal lands are referred to in Sub-clause 1 (i) as follows, in which the name Company means the Canadian Pacific Railway:

> "That if the Company or any other company with whom it shall have any arrangement on the subject shall, by constructing the said railway or any part of it as stipulated for in the said Agreement, become entitled to and shall get any lands as a subsidy from the Government of British Columbia which in the opinion of the Director of the Geological Survey of Canada (expressed in writing) are coal-bearing lands, then the Company will cause to be conveyed to the Crown, in the interest of Canada, a portion thereof to the extent of fifty thousand acres, the same to be of equal value per acre as coal lands with the residue of such lands. The said fifty thousand acres to be selected by the Government in such fair and equitable manner as may be determined by the Governor-in-Council, and to be thereafter held or disposed of or otherwise dealt with by the Government as it may think fit on such conditions, if any, as may be prescribed by the Governor-in-Council, for the purpose of securing a sufficient and suitable supply of coal to the public at reasonable prices, not exceeding two dollars per ton of two thousand pounds free on board cars at the mines.
>
> And on the part of the Government, to pay the said subsidy by instalments as aforesaid."

It is the stipulation in this sub-clause requiring the coal to be sold at $2.00 or less per ton, together with a possible implication that the coal cannot be exported, that prevents exploitation of the coal in these Blocks.

Current Situation—1973. The rising requirements for coal and the consequent substantial increase in mine development in Western Canada have resulted in recent and stronger interest in these Coal Blocks by industry and the federal government.

There has been some dispute between the Government of Canada and the Government of British Columbia as to who controls the coal rights in these two Coal Blocks. The Federal Department of Justice has examined the Provincial arguments and has advised "that the Province does not have any valid claim to the ownership of coal in the lands in question".

In the late 1960's and up to 1971, licences to explore this coal were granted by the Government of Canada to four mining companies. Because of the above mentioned restrictive Sub-clause 1 (i) in the Crow's Nest Pass Agreement and the uncertainty about when such restriction might be removed, the Department of Energy, Mines and Resources did not renew these non-exclusive exploration licences in 1971. The Government of British Columbia also issued exploration licences in these Coal Blocks, which are still in effect.

Potential of the Blocks. The total coal reserves in the Dominion Coal Blocks have been estimated at 8.6 billion short tons or about 10 per cent of the total resources of medium and low volatile bituminous coal in Western Canada. This is a geological estimate and recently (1972) the Department of Energy, Mines and Resources enlisted the services of a consultant to assess how much of the total reserves could be extracted by surface mining at economically acceptable ratios of rock overburden to coal. This consultant concluded that about 110 million tons would be recoverable from Block No. 73. No such study has yet been made on the second Block.

A quantity of 110 million tons is adequate for supporting a very substantial mining operation. The coal has been tested for quality and has been determined to be of good metallurgical grade.

Chapter 2

THE ELECTRIC UTILITY INDUSTRY

The Resource Base and Reserves

Unlike the other sources of energy considered in this report, electricity is not a primary natural resource. It is a secondary or manufactured form of energy and therefore its supply does not consist of discovered resources. However, an increasing percentage of our electrical supply is dependent on reserves of the primary fuels of oil, natural gas, coal and uranium. Some of these primary forms of energy are best suited for use after conversion to electricity. This applies particularly to hydraulic and uranium resources and, increasingly, to the use of coal, especially in the lower grade forms.

Historically in Canada most electric energy has been produced by hydroelectric generation. At the end of 1972 the total installed capactiy of this type was 32,500 megawatts,* and the remaining undeveloped potential has been estimated at between 60,000 and 85,000 megawatts. Although this potential is considerable, the remaining large undeveloped hydro sites are distant from load centres, and are concentrated mainly in Labrador, Quebec, Manitoba, British Columbia and the Yukon Territory. There are economic limitations in developing these resources for supply to existing load centres due to the high cost of transmission and to the need to compete with thermal generation near the load centre, particularly with nuclear plants.

For Canada as a whole, the percentage of electric energy generated in thermal stations has risen from only 6 per cent in 1950 to 25 per cent in 1972, and this upward trend will continue. Nuclear plants contributed over 11 per cent of the total thermal generation in 1972.

The Structure and Nature of the Industry

The main characteristic of the electrical utility industry is its very capital-intensive nature. At the end of 1970 the total assets of the utilities were $16 billion. Fixed assets in 1970 were $290,000 per employee compared with an all-industry average of $10,000. The capital expenditures made by the electrical utilities in 1970 were $1.6 billion, and constituted 15 per cent of the capital expenditures of all Canadian business.

Most of the large electrical utilities in Canada are owned by their respective provincial governments. Government-owned utilities produce about 90 per cent

* 1 megawatt (MW) = 1,000 kilowatts (kW).

of the power generated for sale, and investor-owned utilities about 10 per cent. Unlike the oil and gas industries, the electric power industry in Canada is subject to almost no foreign ownership or control.

Most of the major electrical utilities are interconnected with neighbouring Canadian and United States utilities, and thereby share in the benefits of agreements for mutual assistance, economy energy exchanges and other types of power transfer.

Some manufacturing industries generate part or all of their own power requirements. In 1970 such industries generated 16 per cent of all the electric energy produced in Canada, but this proportion declines year by year. Nearly 85 per cent of this industrial generation is in two prov.nces, Quebec and British Columbia.

Markets and Supplies

Domestic Markets. The market for electricity may be classified by three sectors: residential, commercial, and industrial. The energy consumed by these sectors in Canada during 1971 was as follows:

	Millions kWh	Per cent
Residential	46,500	21.9
Commercial	31,800	15.0
Industrial	116,700	54.8
	195,000	91.7
Losses and unallocated	17,600	8.3
	212,600	100.0

About a third of the industrial consumption is taken by the mineral industries, a third by the pulp and paper companies, and the remaining third by all other industries.

In per capita use of electric energy, Canada stands second of all countries in the world. The top five are as follows: (data are for 1968)

1. Norway	15,633	kWh per capita
2. Canada	8,491	"
3. United States	7,138	"
4. Sweden	6,990	"
5. Luxembourg	5,839	"

Export Markets. Export of electrical energy is not a significant part of Canada's total electric power system. Although net exports were higher in 1972 than in most recent years they amounted to less than four per cent of total generation. Nevertheless exports, as well as imports, are of regional significance to utilities on both sides of the border since they are negotiated to achieve economic and operational benefits for both parties.

Future Requirements and Supplies. During the past 35 years, the total requirements for electric energy in Canada have been growing steadily at a compound rate of 7.1 per cent per annum. In the short term there is every reason to expect this historical growth rate to continue. Towards the end of the period of this review it may taper off somewhat, mainly because of the declining rate of population growth in recent years.

Energy demand projections used in this report suggest the following trend of electrical energy consumption in Canada:

Year	Millions of kilowatt hours
1970	202,300
1980	396,000
1990	698,000
2000	1,132,000

The total consumption of 202,300 in 1970 corresponds to an average use of 9,500 kWh per capita. The requirement of 1,132 billion kWh for the year 2000 corresponds approximately to 32,000 kWh per capita. This estimated three and one-half fold increase in per capita use from 1970 to 2000 compares with an historical fourfold increase experienced from 1935 to 1970 and reflects the trend towards on electrical society as discussed in the main report.

The forecast growth rates of total electric energy consumption in Canada are slightly lower than the corresponding rates forecast for the United States by the Federal Power Commission. This relationship reflects the continuation of the equivalent historical growth rates, which have been slightly lower in Canada than in the U.S.A. The average historical and forecast rates in the two countries are as follows:

	Canada	U.S.A.
Historical 1935–1970	7.1	7.7 approx.
Forecast 1970–1980	7.0	6.9†
Forecast 1980–1990	5.9	6.45†
Forecast 1990–2000	5.3	6.2*

†Federal Power Commission (U.S.) 1970 Power Survey.
*Estimated.

Historically, hydro has been the main source of electricity in Newfoundland, Quebec, Ontario, Manitoba, British Columbia and the territories; it has been a significant component in Nova Scotia, New Brunswick, Saskatchewan and Alberta. Only in Prince Edward Island is there no hydro power. Canada's remaining undeveloped hydro sites are remote from load centres and are concentrated in Labrador, Quebec, Manitoba, British Columbia and the Yukon.

Coal is the fuel used most for the generation of electricity. However, because its transportation cost on a heat content basis is higher than that of other fuels, its use is limited to certain regions of Canada. In the Maritimes, coal production will meet only a decreasing percentage of power generation needs as the utilities turn to more economical generation through the consumption of imported oil or through the development of nuclear plants. Ontario is expected to continue using coal imported from the United States, but its consumption for power generation is not expected to increase significantly as Ontario Hydro turns to the use of imported residual oil and nuclear power. In Saskatchewan the use of strip-mined lignite is expected to expand considerably, and in Alberta a corresponding increase is forecast in the use of strip-mined sub-bituminous coal. In British Columbia hydroelectric power will continue to dominate for some time and coal for thermal-electric purposes is available from the Hat Creek deposits and as a by-product from metallurgical coal mining in the Rockies. Nevertheless the provincial utility can be expected to rely heavily on nuclear power from the mid-1980's onward.

Technological Considerations

The technical problems and challenges facing the electrical utility industry and possible methods by which they may be solved are important elements in a full understanding of the industry and its future expansion. The technical problems associated with pollution and other environmental factors are dealt with in Appendix A, Part 2.

The following estimate shows how these demands will be met in Canada as follows:

	Billions (10^9) kWh			
Source	1970*	1980	1990	2000
	%	%	%	%
Hydro	157 (76.5)	235 (59)	310 (44)	344 (30)
Thermal Total	47 (23.5)	161 (41)	388 (56)	788 (70)
Coal	34 (17)	76 (19)	127 (18)	151 (13)
Oil	7 (3.5)	29 (7)	72 (10)	118 (10)
Natural Gas	5 (2.5)	11 (3)	9 (1)	17 (2)
Nuclear	1 (0.5)	45 (11)	180 (26)	502 (44)
Total	204 (100)	396 (100)	698 (100)	1,132 (100)

*Includes 202.3 x 10^9 kWh domestic consumption plus small net exports.

These projections are presented here to demonstrate two basic trends in the supply mix: the decreasing proportion of electricity which will be derived from hydroelectric generation and the increasing proportion from nuclear generation. The increase in the nuclear energy contribution in 1990 and 2000 is more modest

than in some projections but it is considered prudent not to underestimate the role of fossil fuels.

In general, the supply forecast is based on the continuing use of present methods of generation. Some of the innovations described by this paper may be developed before the end of the century, but it is unlikely that by then their commercial application will become sufficiently widespread to cause major changes in the mix of basic energy resources used for producing electricity.

Other factors which influence the selection of sources of electric generation are the availability of hydro sites, estimated capital costs, fuel prices, fuel transportation costs, and the size of the utility. The interplay of these factors results in different supply patterns in the various regions of Canada.

Hydroelectric generation is still the main source of electric energy in Canada. As a percentage of total production, however, it declined from 94 per cent in 1950 to 76.5 per cent in 1970, and the supply forecast shows it as only 30 per cent by the year 2000.

Basically all the major problems facing the industry today stem from the phenomenal growth in the use of electricity. The annual growth rate of 7.1 per cent over the past 35 years means that every ten years total consumption doubles, and the equipment to supply it must also be doubled. This raises challenges not only in providing the sites and physical equipment, but also in making available the financing needed.

The facilities of electrical utilities fall naturally into the operating classifications of generation, transmission and distribution.

Generation. The undeveloped hydro resources in Canada tend to be the more remote or less economically attractive residue and many will be penalized through high transmission costs. There will, however, be continued development of hydroelectric sites for a number of years taking advantage of improved design and construction techniques, remote control facilities to reduce labour costs and larger developments to take advantage of the economies of scale. Other contributions from hydroelectric systems include stations designed or modified specifically for peaking duty or as pumped-storage installations. In both cases such plants would operate in conjunction with large base-loaded thermal plants or with remote base-loaded hydro developments. Energy from the tides is another possible hydro development, but studies to date indicate that even Canada's most attractive site in the Bay of Fundy will be very difficult to justify on an economic basis compared with alternative generation options.

Thermal generating plants are becoming increasingly competitive as efficiencies are improved and costs reduced with larger scale, higher temperature units and by improvements in environmental protection features. In addition, there is a movement away from the more rapidly depleting fuels (oil, gas) to coal and nuclear fuels. The significant promise of the CANDU system which requires no enrichment facilities and the large reserves of nuclear fuels in Canada all combine to ensure that this system will make a very important contribution to Canada's electrical energy needs for many decades to come. This may make Canada's needs for some alternative forms of energy generation less significant than for some other countries.

The nuclear breeder reactor for example, will likely be much less important for Canada than for countries using enriched uranium fuel supplies. Ultimately, Canada will need, like the rest of the world, a solution to the nuclear fusion process of generation which will open up almost unlimited sources of energy in the electrical form. It will be important for Canada to judge properly the timing and type of research and development involvement in fusion technology.

There is interest in some locations in fuel cells which provide for direct conversion to electrical energy in a chemical cell reaction. This may be of particular interest for serving electrical loads in some remote areas as an alternative to diesel generation. Magnetohydrodynamics (MHD) is a system for direct conversion to direct current from a high temperature ionized stream of gas. It has an efficiency advantage resulting directly from the high temperatures used, but this also presents a challenge in finding materials capable of continuous use at those temperatures. Unless MHD systems can be successfully developed for the more abundant fossil fuels, e.g. coal, there would be relatively little interest for Canada. Geothermal energy prospects are much less promising in Canada than in other regions with more promising geological conditions. All of these technologies are referred to in more detail in Appendix A.

In summary, it seems appropriate for Canada to emphasize the refinement of its skills in hydroelectric systems directed primarily to completing, in the most economical and environmentally acceptable manner, the available remote hydro sites and the development of peaking and storage systems which take advantage of the flexibility of hydroelectric units. The other priorities appear to lie primarily in the nuclear area, involving the refinement of the thermal reactor and appropriate contributions over a relatively long period towards the development of fusion techniques.

Transmission. Canada's geography has determined that long distance transmission of electric power is of key interest in the country's energy development. This results from the need to exploit remote sources of hydroelectric energy as well as to maximize the advantages of interconnections between regions. Significant pioneering has taken place on Canadian systems, especially at higher voltages up to the 735 kV level adopted by Hydro Quebec.

Canada has more operating direct-current (DC) transmission mileage than any other single country in the world and the most recent installation has effectively demonstrated new technology employing thyristor equipment which promises to significantly expand the opportunities for DC systems.

Initial research is under way in cooperation with other countries on ultra-high voltage (UHV) transmission and voltages above 750 kV which may be essential to meet some of Canada's future transmission needs. There are challenges not only in the economics and techniques of transmission, but also the required size of structures tends to make this aspect of the engineering an increasingly difficult part of the task. On the other hand, these higher voltages have the capability of moving much larger quantities of power in a limited physical space. Underground and underwater transmission is also significant in some regions of Canada. The former will be required for bulk transmission into the larger urban centres and the latter is already in use between Vancouver Island and the mainland. It may

also have application in Newfoundland and Prince Edward Island for high capacity links.

Transmission is important not only for connecting remote generating sites to the load centre, but also for interconnecting adjacent regional transmission systems. Such interconnection frequently allows for lower reserve capacities in the individual utilities and permits generation from the lowest cost source at any given time. Interconnections require not only the physical transmission facilities, but also increasingly sophisticated control systems so that satisfactory parallel operation can be achieved. There are currently only two significant gaps in the interconnection of Canadian utilities, namely between Saskatchewan and Alberta and between Ontario and Quebec. This latter gap has not prevented advantage being taken of transfers of power between these two provinces; when surplus capacity is available in Quebec groups of generators at the Beauharnois generating station of Hydro Quebec are isolated from the Quebec system and connected to the Ontario network. However, this arrangement is likely to be suitable on an increasing scale only for a limited period of time which points up the desirability of closing this gap with a high-capacity interconnection.

High voltage DC equipment may well provide the opportunity to close these remaining gaps in a manner which will ensure satisfactory system performance and achieve economic benefit.

Distribution. Although less spectacular, the distribution equipment in Canada represents about 25 per cent of the combined equipment investment. It is not only significant from a cost point of view, but its reliability of performance ultimately determines whether or not the customer receives a supply of power. The percentage of total costs represented by distribution investment is somewhat lower in Canada than in other countries because of the more capital intensive nature of large hydro generating facilities and the longer transmission circuits.

Being geographically more widespread and closer to the ultimate customer the appearance of distribution systems is being given increasing attention. While underground systems are generally substantially higher in cost, reliability can be better than conventional systems and new techniques are being developed to minimize the extra cost burden on the consumer. To some extent this is easier to do when customer density and load per customer is increasing. Where load densities are lower, efforts are being made, as with high voltage transmission, to retain overhead circuits but with substantially improved appearance for the subtransmission and distribution lines.

The increasing reliability of service to the ultimate customer is emphasized by the growing dependence of the community on electrical energy. Even short interruptions can become inconvenient or even serious. While certain essential services associated with hospital, transportation and communication systems may require back-up supplies for emergencies there are many other uses such as for elevators in high-rise buildings and auxiliary equipment for heating systems, where, although the amount may be relatively small, the availability of electrical energy is essential. It can be seen then, that in distribution of electrical energy, as with generation and transmission, there is an interesting combination of future opportunities and challenges.

Federal Government Policies

In 1963 the present National Power Policy was announced in the Canadian House of Commons. The aim of this policy was to encourage the provision of electricity to Canadians at the lowest possible cost, and to establish a flexible export policy to enable the development of large projects which might not be viable without a significant portion of their output being exported initially.

The export policy was developed principally with hydro projects in mind, but its principles and objectives can be applied to other generating projects where export for a limited period provides some savings in scale and pace of construction which are of benefit ultimately to the Canadian consumer.

Of significance in relation to energy policies, the Government of Canada has supported development in nuclear power through Atomic Energy of Canada Ltd., and in other areas of energy research through support of the development of the Hydro Quebec Research Institute (IREQ). A number of the industry support programs of the Department of Industry, Trade and Commerce have also played a part in developing the equipment needs of the electric utility industry.

Several programs have been employed to improve transmission systems and interconnections, including the financing provisions of the Atlantic Provinces Power Development Act and the construction by the federal government of the Nelson River Transmission System in Manitoba.

In 1968 the report of the Federal–Provincial Committee on Long Distance Transmission recommended that a nationally integrated transmission network was not justified on economic and technical grounds but that regional interconnections should be developed whenever they were justified. This recommendation has been followed, and substantial reinforcement of regional interconnections has taken place with assistance in some cases from the federal government. Other interconnections are being examined.

Future federal policies must be designed to improve the ability of electric utilities to meet the demands of a growing market and at the same time to avoid distortions in the utility expansion plan through selective subsidies.

Federal environmental policies together with their provincial counterparts will have an increasing effect on electric utilities and it will be important to ensure that such policies produce adequate benefits to society as a whole and do not burden the consumer of the commodity with unreasonable or unnecessary costs. In capital financing close coordination will be required between the policy directly relating to the electric utility industry and the related financial and industrial development policies.

The system for licensing exports of electrical energy by the National Energy Board must continue to provide adequate protection to the Canadian consumer against export agreements which might adversely affect the cost, security or availability of domestic supplies. On the other hand, the consumer must also be assured that the licensing system does not prevent the realization of opportunities where export contracts can produce short or long-term benefits to the domestic customer. This may include the opportunity to use larger generating units than can be justified on an isolated Canadian system or to sell energy which, due to

the optimum timing of plant construction, is available for a limited period following the completion of a large project. There may also be increasing opportunities for diversity sales on a seasonal basis between adjacent Canadian and U.S. utilities.

Summary

Electric utilities are thus seen to be highly capital intensive, largely provincially owned and regulated, and, in addition, subject to regulation by the federal government as regards exports. They face substantial challenges in the future in the development and acquisition of the technology needed for continued growth within acceptable levels of environmental disturbance and also in making a substantial contribution to Canada's total energy needs by using, in large measure, raw energy resources which are unsuited for other uses.

Chapter 3

THE NUCLEAR POWER INDUSTRY IN CANADA[1]

INTRODUCTION

The present Canadian nuclear power program is based upon the CANDU heavy water moderated reactor concept. This design is the culmination of over 20 years of research and development by Atomic Energy of Canada Limited (AECL), the government agency formed in 1952 to continue the work begun at Chalk River by the National Research Council.

The first reactor to operate outside of the United States was the ZEEP heavy water moderated natural uranium, zero energy reactor built at Chalk River in 1945. It was followed two years later by the 20 megawatt NRX research reactor also using natural uranium and heavy water. This very successful research reactor was built almost entirely by Canadian industry. It was modified in the early 1950's and its power increased to 40 megawatts. Later it was essentially copied for the CIRUS research reactor at Trombay, India and recently for the Taiwan Research Reactor.

AECL has built two further heavy water moderated research reactors; the 200 megawatt heavy water cooled NRU reactor at Chalk River, which went into operation in 1958, and the 40 megawatt organic-cooled, WR-1 reactor, at the Whiteshell Nuclear Research Establishment which began operation in 1965.

Based upon the knowledge gained through the NRX reactor, AECL in the early 1950's formed a study group with representatives from utilities and industry to develop a conceptual design for a heavy water moderated and cooled power reactor. In 1955 the Canadian General Electric Co. Ltd. formed a team to design in conjunction with AECL and the Hydro Electric Power Commission of Ontario (Ontario Hydro) the 20 MW(e) NPD demonstration power reactor based upon this conceptual design. In 1958 AECL created its Power Projects group to design the first full scale power station at Douglas Point. Since then the AECL Power Projects group has designed, in conjunction with Ontario Hydro, the 4 x 500

[1] For the purpose of this report the nuclear industry will be deemed to include those aspects of Canadian research, development, engineering, manufacturing, operating and financing directly related to the nuclear power program, but excluding uranium mining and refining. The fabrication of reactor fuel is included beginning with reactor grade UO_2, whose preparation is covered in the appendix on the uranium industry. An important part of the nuclear program which is excluded from this appendix is the development, production and use of radioisotopes.

MW(e) Pickering and the 4 x 750 MW(e) Bruce Generating Stations, and, in conjunction with Hydro Quebec, the 250 MW(e) Gentilly-1 nuclear power station. AECL Power Projects has also supplied a large amount of design and development expertise to the Indian Department of Atomic Energy for the Rajasthan Atomic Power Project, with two reactors based upon the Douglas Point design. RAPP-1 began operation in 1972. Canadian General Electric designed and built the 137 MW(e) KANUPP nuclear power station near Karachi, Pakistan, which went into service in 1971.

As of March 1973 there were about 2,000 megawatts (electrical) of nuclear power capacity operational in Canada and 4,100 megawatts under construction or committed. It is estimated that by 1985 there will be about 15,000 megawatts of nuclear power capacity installed in Canada. By 1990 this is expected to grow to over 30,000 megawatts and by the year 2000 to about 100,000 megawatts. By 1972 dollars this represents a total expenditure to 1990 of $12 to $15 billion and to the year 2000 of over $50 billion.

The CANDU reactor has two marked differences from the more universally used American light water reactors; namely the use of natural uranium for fuel and the use of pressure tubes instead of pressure vessels. The former has permitted the development of a completely indigenous fuel manufacturing industry while the latter has permitted smaller Canadian industries to manufacture all of the essential components for CANDU reactors. No firm in Canada is capable of building the large pressure vessels necessary for the U.S. reactors.

Structure of Industry

General. Canada's successful nuclear power program is a result of a unique collaboration of government, electrical utilities and industry. A special cooperation between Atomic Energy of Canada Limited and Ontario Hydro has existed since the conceptual design studies undertaken in the early 1950's by AECL, utilities and industry.

Research and Development. Atomic Energy of Canada Limited, utilizing its research reactors and strong team of basic and applied scientists, has performed almost all of the research and development which has been the basis for the successful evoluton of the CANDU nuclear power stations. Over 3,000 people are engaged at the two major research centres of Chalk River and Whiteshell in research and development and the support activities involved.

Engineering. In 1958 AECL set up the Power Projects group in Toronto to design the Douglas Point Generating Station. This organization, which now has a staff of about 900, has performed the nuclear engineering for all of the Canadian nuclear power stations since NPD. In the case of the Pickering and Bruce stations of Ontario Hydro, AECL Power Projects served as the prime nuclear design consultant and also acted as the procurement agent for the components of the nuclear steam supply system. Ontario Hydro has performed its own engineering of the civil structures and services. In the case of the Gentilly station, much greater use was made of consulting engineering firms, especially for civil engineering and design

of services. Some engineering is supplied by the manufacturers of the major components; for example, a major heat exchanger may be purchased on operating specifications with the detailed design to be done by the manufacturer.

Canadian General Electric (CGE) designed the NPD station, the KANUPP station in Pakistan and the WR-1 research reactor. It has now disbanded its project design team, concentrating on fuel, fueling machines and other components.

A few major engineering consulting firms have been involved in the overall design and construction of projects such as the Taiwan Research Reactor and the heavy water production plants. They have also designed special components such as the fueling machines and have been engaged in various special aspects of the design of the several nuclear power stations built to date.

Manufacturing. Many Canadian firms have supplied components and equipment for the Canadian nuclear power plants which have been built or are under construction. In most cases the firms have been supplying equipment similar to that which they normally supply to other industries, but, in many cases it has been of a special design or enhanced quality to meet the requirement of the nuclear design. The manufacturing and supply industry, and heavy water production industry, an essential component of the overall Canadian nuclear program, are discussed in later sections of this report.

Ontario Hydro has acted as its own prime contractor for the civil structures and for general installation of equipment for the Pickering and Bruce stations.

Operations. A significant aspect of the industry is the operation of the nuclear power plants by the utilities. The complexity and novelty of nuclear power plants require larger staffs than equivalent fossil fuel plants and require new talents and skills. To develop the necessary skills and knowledge, Ontario Hydro has developed an extensive training program and has established a training centre adjacent to the NPD station which makes use of the plant for practical training. The nuclear operations staff of Ontario Hydro currently numbers about 1,300. By 1980 this is expected to grow to 2,500 and by 1990 to 5,000, most of whom will require specialized training.

Cost Distribution

The total capital cost of a large nuclear power plant in 1972 was about $400 per kilowatt. This can be compared to about $200 per kilowatt for a coal-burning station. However, the fueling cost of a nuclear plant is only about one fifth that of a coal-fired station so that the overall unit energy cost of a nuclear station is less than that of a coal or oil-fired station.

A typical breakdown of the capital cost of a large CANDU nuclear power station is shown in Table 1. Of the total capital cost about two thirds can be related to the nuclear plant if one includes in addition to the reactor boiler, the special containment buildings, control systems, other special systems, design, commissioning, fuel and heavy water. The last item alone accounts for about 15 per cent of the total capital cost. With the anticipated growth of the nuclear power program in Canada, the total business for the nuclear-related portion of new power plants will probably exceed $0.5 billion a year in the early 1980's.

TABLE 1

TYPICAL CAPITAL COST BREAKDOWN
(CANDU Nuclear Power Station)

	Per Cent
Direct Costs	
Site, buildings and structures	10.0
Reactor boiler and auxiliaries	15.0
Turbine generator and auxiliaries	9.0
Electrical power systems	4.5
Common processes and services	4.5
Instrumentation and control	3.5
Initial fuel (half first charge)	1.5
Heavy water	15.0
	63.0
Other Costs	
Design engineering	8.0
Construction and field engineering	9.0
Commission	3.0
Administration and miscellaneous	2.0
Interest during construction and escalation	15.0
	37.0
Total	100.0

HEAVY WATER

An essential component of the CANDU nuclear reactor system is heavy water. All of the nuclear power plants to date, with the exception of Gentilly-1, have used heavy water not only as a moderator, but also as the primary coolant. In such designs approximately one ton of heavy water is required for one megawatt electrical capacity.

Heavy water is the compound formed from 2 atoms of deuterium (an isotope of hydrogen) and one of oxygen—symbol D_2O. It is similar to ordinary water both chemically and physically but with a density about 10 per cent greater than that of ordinary water. The nuclear properties of H_2O and D_2O show large differences, however. The most important difference is that, in a nuclear reactor, heavy water is a much more efficient moderating material than ordinary water. Its use as moderator enables the reactor to be fueled with natural uranium. For light water reactors to operate, the fuel has to be enriched.

All compounds of hydrogen contain some deuterium. The ratio in nature is usually between 6,000 and 9,000 expressed as atoms of H per atom of D. The concentration in Canadian waters expressed in atoms per million atoms is shown in Figure 1.

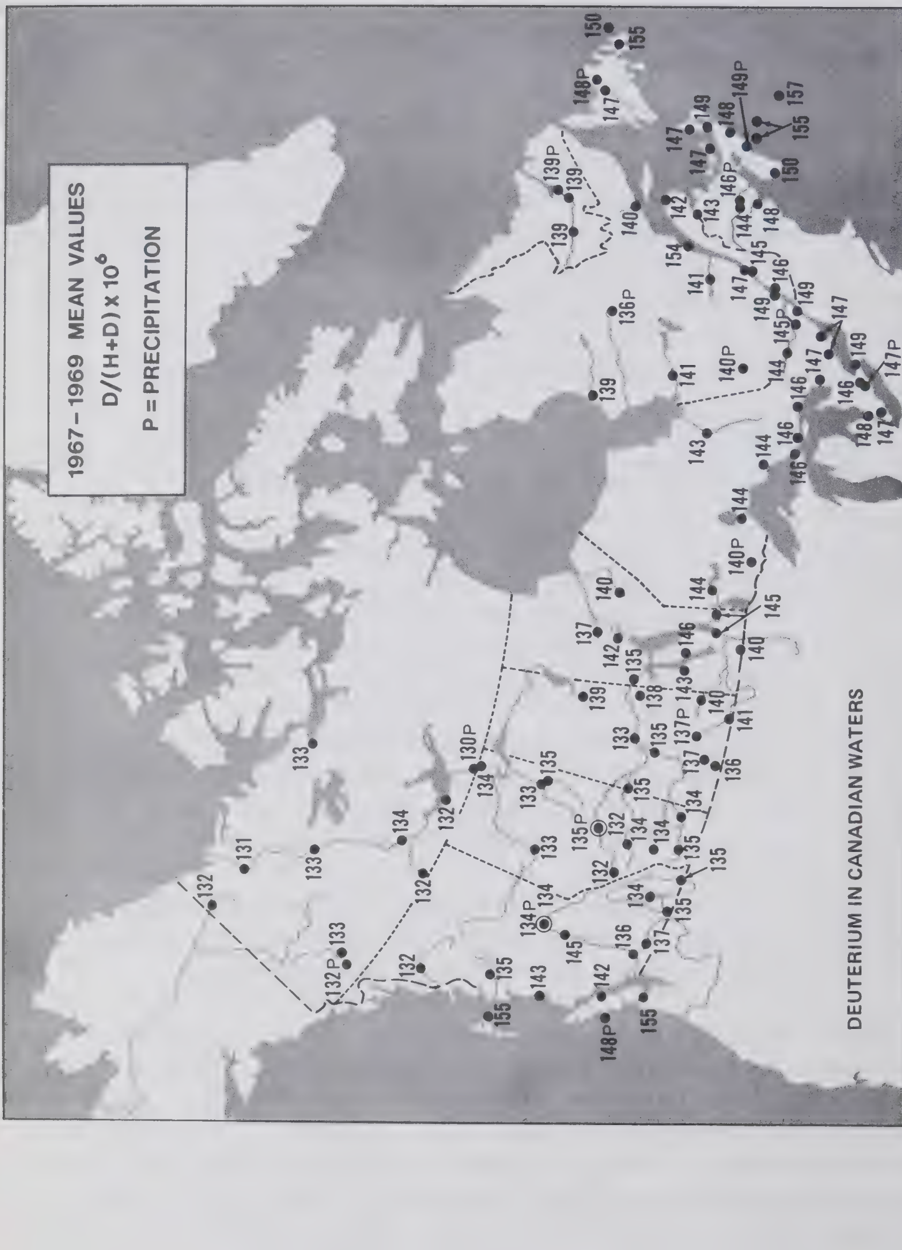
1967 – 1969 MEAN VALUES
D/(H+D) x 10⁶
P = PRECIPITATION
DEUTERIUM IN CANADIAN WATERS

Figure 1

Heavy water was produced in Canada from 1943 to 1956 at a plant operated by the Consolidated Mining and Smelting Company at Trail, B.C. This small plant provided most of the early heavy water requirements in both Canada and United States. Subsequent Canadian requirements have been purchased mostly from the United States Atomic Energy Commission.

Many processes have been suggested for heavy water production, but only one has been operated on a scale large enough to supply heavy water for a nuclear power program. This is the Girdler-Sulfide process which uses the exchange of deuterium between water and hydrogen sulphide at two temperatures. Two plants using this process were built for the USAEC in 1951-52. Canada's heavy water plants are based on this technology which was acquired as part of an exchange between AECL and the USAEC.

Canada's first large scale heavy water plant was built by Deuterium of Canada Limited at Glace Bay, Nova Scotia. This plant was beset with difficulties during construction which were then complicated by a protracted commissioning period. Attempts to bring it into operation were finally abandoned when extensive corrosion was discovered in heat exchangers cooled by sea water. This plant, which is now owned by the Government of Nova Scotia, is being rehabilitated by the Canadian government through Atomic Energy of Canada Limited. It is now expected to begin operation in 1975.

The Canadian General Electric Company initiated construction of the Port Hawkesbury Heavy Water plant in 1966 and began production in late 1970. The first two years of operation were interrupted by technical problems requiring modification to some items of equipment and instrumentation and by breakdown in the steam supply from a nearby steam plant. In early 1973 the plant was operating at about 60 per cent of its 400 ton per year design capacity.

In 1969 AECL began construction of the Bruce Heavy Water plant employing the same basic arrangement as in the Port Hawkesbury plant, but consisting of two parallel units each having a capacity of about 400 tons per year. The first unit began operation in the spring of 1973 and the second unit is scheduled to follow in the summer of 1973.

The investment in the Port Hawkesbury and Bruce Heavy Water plants and in the rehabilitation of the Glace Bay plant will total about $400 million. Additional heavy water plants will be required to meet the requirements for heavy water of the predicted CANDU nuclear power program in the 1980's. By the late 1980's the annual demand for heavy water could exceed 3,000 tons/year with a value, in 1972 dollars, of about $150 million.

Fuel

Beginning with NPD all fuel for Canadian power reactors has been manufactured as bundles of elements $19\frac{1}{2}''$ long. Approximately 700 tons of uranium have been fabricated into about 40,000 fuel bundles for Canadian reactors. This fuel has been worth about $27 million of which about $18 million represents the fabrication costs, the remainder being the cost of the uranium. The annual consumption is about 0.1 ton of uranium per year per MW(e) operating at 80 per cent capacity. Annual demand is expected to reach 3,000 tons/year by 1990 and 10,000 tons/

year by 2000. In 1972 dollars, this fuel will be worth, about $150 million/year and $500 million/year respectively.

There are two fuel manufacturing firms in Canada, each having plants capable of fabricating about 200 tons of fuel annually.

Canadian Content

Much of a nuclear power plant is comprised of civil engineering structures and systems similar to other power plants and industrial systems. All of this can be suppled readily by Canadian industry. Of the special components comprising the nuclear steam supply system currently about 60 per cent of the equipment and materials is supplied domestically. As the nuclear steam supply comprises a value of about $200 million for a station such as the Bruce Generating station the expenditures in Canada for specialized nuclear equipment amounts to about $120 million. Overall, more than 80 per cent of the materials, equipment, and services for current nuclear power plants is supplied from within the country. In addition all of the engineering and development is done in Canada.

As the industry grows, the domestic component of the nuclear steam supply system is likely to rise to about 80 per cent and for the overall plant to about 90 per cent. With the expected growth of the nuclear power program this will mean an expenditure in Canada, in 1972 dollars, of about $500 million/year in the late 1970's rising to about $1600 million/year in the late 1980's.

Employment

The direct employment in the nuclear power industry by the year 1975 is expected to be about: 4,000 in construction, 1,200 in operation, 600 in heavy water production, 1,200 in design and engineering and 3,000 in research and development. By 1990 these figures are expected to rise to: construction 16,000, operation 4,500, heavy water production 1,200, design and engineering 3,000, research and development 3,000. These numbers exclude employment in industries which manufacture components for nuclear plants.

Summary

As a result of over two decades of Canadian research and development in the atomic energy field a unique and successful nuclear power system has been developed which is particularly suited to Canadian power utility needs and to the capabilities of Canadian industry. It is expected that the investment in nuclear power in Canada will approach $50 billion by the year 2000 and that 90 per cent of this expenditure will be made within the country.

Chapter 4

THE OIL AND GAS INDUSTRIES

During the first decade of the century, overall energy consumption in Canada increased very rapidly. During this period the use of coal expanded as industrialization of the country proceeded and the rail transportation network grew. Until the early 1930's energy supply and demand were dominated by solid fuels, such as wood and coal.

The second World War and the post-war years witnessed further periods of rapid increase in Canadian energy use, spearheaded this time by the impressive developments of the domestic petroleum industry. Although the rate of growth of total energy levelled out somewhat during the decade 1950-1960, a resurgence has taken place since 1960. The petroleum industry maintained high rates of growth throughout the period, although there was a shift from high rates of growth of oil to high rates of growth of natural gas.

The Shifts Between Energy Sources

While wood and coal supplied 90 per cent of Canada's primary energy requirements in 1900, by 1950 their share had fallen to about half, reaching less than 15 per cent of total actual energy supplied in 1970.

Petroleum, virtually absent from the scene at the beginning of the century, surpassed wood fuel in importance by the 1930's, its use increasing steadily until it accounted for almost 20 per cent of energy consumption by the end of the second World War. Thereafter, growth in petroleum use was rapid, chiefly at the expense of coal.

The rapid increases in the use of natural gas commenced in the 1950's. All this time, electricity from water power had been increasing steadily in importance to become, by 1960, the source of more than one quarter of all energy used in Canada.

THE OIL INDUSTRY

Its Historical Development and Present Status

While oil production can be traced in Canada as far back as the 1850's—to the earliest days of the industry—it was of little consequence until after the Leduc discovery in Alberta in 1947. Since that time exploration and development have proceeded rapidly. The Canadian oil industry, from the point of view of significant production is thus relatively young.

PRIMARY ENERGY CONSUMPTION

(in Btu's 10^{12})

	1900	1920	1940	1960	1970	1972
Oil[1]	4	78	319	1,668	2,836	3,110
Gas		5	43	382	1,250	1,405
Coal	270	856	917	556	709	705
Hydro[2]	50	50	305	1,014	1,560	1,700
Nuclear[2]					10	70
Wood	186	186	210	120	80	70
Total	510	1,175	1,794	3,740	6,445	7,060

SOURCE: 1990–1920. Compiled by NEB from various sources.
1940. John Davis, Canadian Energy Prospects.
1960–1970. National Energy Board.
1972. Estimate.

[1]Excludes non-fuel petroleum products.
[2]Input equivalent of 10,000 Btu's per kWh.

PRIMARY ENERGY CONSUMPTION

(Percentages)

	1900	1920	1940	1960	1970	1972
Oil[1]	0.8	6.6	17.8	44.6	44.0	44.0
Gas		0.4	2.4	10.2	19.4	19.9
Coal	52.9	72.9	51.1	14.9	11.0	10.0
Hydro[2]	9.8	4.3	17.0	27.1	24.2	24.1
Nuclear[2]					0.1	1.0
Wood	36.5	15.8	11.7	3.2	1.3	1.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

[1]Excludes non-fuel petroleum products.
[2]Input equivalent of 10,000 Btu's per kWh.

Refining, on the other hand, has been significant in Canada over a long period. For example, there have been a number of refineries at Montreal processing imported crude oils for many years. The experience accumulated in this long period helped in the rapid expansion of refining as Canadian crude oil increasingly became available after 1947, first in Western Canada and later as far east as Toronto. At the present time Canadian demands are served by 40 refineries extending across Canada, having a total capacity of just over 1.7 million barrels per day.

The following table gives a listing of some of the more important events in the history of the Canadian oil and natural gas industries.

HISTORICAL MILESTONES OF CANADA'S OIL AND GAS INDUSTRY

1858. North America's first producing oil well in Ontario.
1914. Turner Valley oil discovery.
1947. Leduc oil discovery.
1950. Interprovincial Pipe Lines oil shipment as far east as Superior, Wisconsin.
1953. Trans Mountain Oil Pipe Lines oil shipment to Vancouver.
1954. Direct oil shipments to Sarnia.
1954. Direct oil shipments to Puget Sound.
1957. Westcoast Transmission Co. Ltd. natural gas line to Vancouver completed.
1958. TransCanada PipeLines Ltd. natural gas line to Eastern Canada completed.
1959. National Energy Board established.
1961. National Oil Policy established.
1965. Marketable gas production reaches one trillion (10^{12}) cubic feet.
1966. Liquid hydrocarbon production reaches 1 million barrels per day.
1969. Arctic Islands gas discovery.
1970. Liquid hydrocarbon production equals domestic demand for the first time.
1970. Mackenzie Delta oil discovery.
1970. Canada for the first time denies full authorization for additional exports of natural gas for reasons of inadequate surplus.
1972. Exports of gas reach one trillion (10^{12}) cubic feet.
1973. Oil exports exceed one million barrels per day.
1973. Canada imposes oil export controls.

The Structure and Nature of the Oil Industry. The Canadian oil industry is among the world's most modern in terms of fully integrated development. Notwithstanding the many companies that are active in Canada, the industry is dominated by a relatively few vertically integrated concerns and these have international affiliations and a high degree of foreign ownership and control.

It is difficult to separate some data into oil and gas categories, especially for the exploration phase. However, some impression of the dimensions of the Canadian oil and gas industry may be gathered from the fact that from 1947 to 1962 some $6,200 millions were invested in exploration, development, and production facilities. Since 1962 however, $12,100 millions have been invested by the industry. It appears now that industry expenditures in 1973 alone will reach almost $2,000 millions.

A high proportion of the capital invested has come from sources external to Canada, mainly from the United States, although supplementary funds coming from the United Kingdom and elsewhere are not insignificant. There are disadvantages in the relatively low Canadian financial participation in the oil and gas development program. However, those familiar with the industry will appreciate that there are compensations, not the least of which is the contribution of skills and experience which such international investment brings with it.

Refining and marketing of oil is characteristically carried out in Canada by fully integrated oil companies, most of which are associated with major international oil companies. Smaller non-integrated companies have been significant in exploring and developing our oil and gas resources although the role of these companies is becoming more difficult as exploration is extended to more expensive drilling in the north and the offshore and in the areas of more deeply buried sediments.

CANADIAN OIL AND GAS, BASIC DATA

	1960	1962	1964	1966	1968	1970	1972
Proven Remaining Reserves:							
Marketable Natural Gas [trillion cubic feet (10^{12})]	—	Not Comparable	—	43.2	47.4	53.1	52.9
Liquid Hydrocarbons [billion barrels (10^9)]	4.2	5.2	7.1	9.1	10.0	10.4	9.7
Natural Gas:							
Marketable Production [billion cubic feet (10^9)]	443.0	769.1	947.3	1,106.7	1,378.3	1,839.4	2,252
Canadian Consumption [billion cubic feet (10^9)]	332.0	432.0	555.7	702.0	850.6	1,043.7	1,256
Exports to United States [billion cubic feet (10^9)]	109.8	342.8	392.2	431.8	604.5	780.2	1,012
Imports from United States [billion cubic feet (10^9)]	5.5	5.5	9.6	44.6	81.6	10.9	16
Liquid Hydrocarbons:							
Production (thousand barrels daily)	543.4	731.2	847.7	1,012.6	1,196.3	1,476.1	1,819
Canadian Consumption (thousand barrels daily)	860.0	938.2	1,056.5	1,202.8	1,343.6	1,466.3	1,589
Exports, crude and products (thousand barrels daily)	122.9	252.4	303.4	385.7	517.4	763.0	1,144
Imports, crude and products (thousand barrels daily)	343.1	451.5	504.2	597.8	685.9	762.2	899

1972 Estimate.

The influence of the United States industry has been particularly apparent in Canada. Progressively, a few Canadian characteristics have been added. Known techniques were adopted and new ones were developed to meet the special circumstances of the Canadian scene and in so doing the Canadian industry has demonstrated its capacity for innovation.

The industry encompasses not only the production and refining facilities, but also the transportation facilities running east and west. Oil reaches the west coast via Trans Mountain Oil Pipe Line and the Sarnia–Toronto refining area via Interprovincial Pipe Line. The Montreal refining complex is supplied mainly through the Portland Pipeline, originating in Portland, Maine. Refineries in the Atlantic Provinces and one near Quebec City are supplied directly by tankers.

The Supply and Demand Balance. The Canadian oil market is supplied from indigenous sources and from imports. For the first time in 1970 exports compensated for imports on a volume basis, thus giving Canada a net self-sufficiency in oil. This net position improved to nearly 250 thousand barrels per day (Mbd) in 1972.

PETROLEUM SUPPLY AND DEMAND BALANCE REFINERY FEED STOCKS AND PRODUCTS

(*in thousands of barrels daily*)

	1955	*1965*	*1970*	*1972*	*Average Annual Per Cent Growth*
Production	360	923	1,476	1,819	10.0
Imports	341	558	762	899	5.9
Total supply	701	1,481	2,239	2,718	8.3
Domestic demand	645	1,145	1,466	1,589	5.4
Exports	49	325	763	1,144	20.0
Total demand	694	1,470	2,229	2,733	8.4
Exports minus imports	−292	−233	1	246	

SOURCE: Provincial and Statistics Canada reports.
1972 Estimate.

Canada exports crude oil to the Puget Sound in the U.S. Pacific Northwest, to the northern Middle West States and as far east as Buffalo. Petroleum product exports now are principally from Eastern Canada and are refined from imported crude oil.

In early 1973 oil exports reached such levels that together with demand from Canadian refiners, the level of oil production and pipeline capacity was hard pressed to meet demand. As a result Canada now controls the level of exports of crude oil and equivalent hydrocarbons.

The Production of Oil. While oil is produced in all western provinces, the bulk of the production is in Alberta with over 80 per cent originating from that province in 1972. The following table sets out the production levels achieved:

PRODUCTION OF CRUDE PETROLEUM AND NATURAL GAS LIQUIDS

(in thousands of barrels daily)

	1955	*1965*	*1970*	*1972*
Ontario	1	3	3	2
Manitoba	11	14	16	14
Saskatchewan	31	244	249	241
Alberta	317	618	1,131	1,486
British Columbia	—	42	75	73
N.W.T.	*	2	2	3
Canada	360	923	1,476	1,819

SOURCE: Provincial oil and gas reports.
*Included with Alberta.
1972 Estimate.

The Marketing of Oil. The history of petroleum consumption in Canada parallels that in most other western countries, with the use of kerosene being dominant until, in the first decade of the twentieth century, large-scale use of internal combustion engines made motor gasoline the largest volume petroleum derivative. The increase in motor gasoline use in Canada has been steep and steady, from 23,500 barrels per day in 1926 to 500,000 barrels per day in 1972.

Distillate fuels include light fuel oils used in residential and commercial heating, as well as diesel fuel used by railroads, and for trucking, farming and construction. Heavy fuel oils are generally used for industrial process heat, for the generation of electricity and for ships' bunkering. Other products include fuels for aircraft, lubricating oils and greases as well as asphalt and petroleum coke. Some of the remaining products of petroleum are used as petro-chemical feedstocks.

Early refineries were generally located near the area of crude oil production. Since the early 1950's the trend changed to having refineries near consumption centres. Such developments have resulted in crude oil entering more and more into international trade. However, in very recent years, some return to the earlier practice has been noticeable. An example of this is the consolidation of refining in the Edmonton area.

Even without large-scale indigenous oil and gas availability, Canadian petroleum demand almost doubled between 1945 and 1950. During the same period, the total use of coal began to stagnate at the level achieved in 1945.

The expansion of petroleum use has been a worldwide phenomenon, although it occurred relatively early in Canada based primarily on the new technology of the automated burner used for both residential and commercial heating. In the industrial field, competitive forces led to the ready acceptance of fuel oil as a substitute for coal. In addition, the private automobile advanced the demand

for petroleum, and trucking made inroads in the overall transportation field. During this period, the railroads converted much of their coal-using operations, first to heavy fuel oil and, in the mid-fifties, to diesel fuel.

The following table shows the growth in demand for the various petroleum products in Canada:

Domestic Demand for Petroleum Products
(in thousands of barrels daily)

	1955	*1965*	*1970*	*1972*	*Average Annual Per Cent Growth*
Motor gasoline	211	353	455	502	5.2
Middle distillates	197	362	446	490	5.5
Heavy fuel oil	122	212	270	289	5.2
Other products	71	138	198	207	6.5
Net sales	601	1,065	1,369	1,488	5.5
Industry use	44	80	97	101	5.0
Domestic demand	645	1,145	1,466	1,589	5.4

Source: Statistics Canada, Refined Petroleum Products.
1972 Estimate.

The absence of natural gas in the Atlantic Provinces and the marginal competitiveness of natural gas in Quebec, together with the decline in coal use, has resulted in the rapid increase in petroleum use throughout this eastern area. This trend is shown in the following table:

Petroleum Demand in Atlantic Provinces and Quebec
(in thousands of barrels daily)

	1955	*1965*	*1970*	*1972*	*Average Annual Per Cent Growth*
Domestic Demand					
Canada	645	1,145	1,466	1,589	5.4
Atlantic and Quebec	220	462	622	700	7.0
Percentage of Canada	34.1	40.3	42.4	44.0	

Source: Statistics Canada, Refined Petroleum Products.
1972 Estimate.

Conversely the growth in demand for crude oil in the area west of the Ottawa Valley which is served from Western Canada, has been slower. This slower growth is largely due to the presence of natural gas competition and also because heavy fuel oil refined from foreign crude is allowed freely into the otherwise protected market.

As a result of pressures from a worldwide over-supply of crude oil, domestic production in both the United States and Canada became threatened in the late 1950's. The United States reacted with quotas, first voluntary and then in 1959 mandatory, to restrict imports of crude oil and certain products. Canada then negotiated the "overland exemption" which gave access to the United States market for Canadian crude oil under minimal restrictions and then, finding its Ontario markets being exposed to pressure of world oil supplies in 1961, announced a policy which gave western Canadian crude oil a reasonably assured market west of the Ottawa Valley.

This geographic division ensured that Canada's wellhead price structure and the lighter products obtained from Canadian crude oil did not have to come into direct competition with world crude oil prices in serving a portion of domestic demand in Canada.

The pricing of Canadian oil had varied as the industry expanded. With the discovery of major oil and gas fields in Alberta and Saskatchewan there came a drive for markets, both in Canada and the United States. This development had a salutary effect in that it reduced Canadian prices of petroleum products which previously had been imported. The eastward expansion of the crude oil pipeline system to Superior, Wisconsin and later to Sarnia and Toronto established a new pricing point for western Canadian crude oil in competition with supplies from the United States.

In the 1950's U.S. domination of the world price mechanism began to wane. However, until the late 1950's Canadian wellhead prices were essentially determined by the price at which U.S. crude might be laid into Sarnia. United States prices, in turn, were the basing point for world crude prices.

The break with world crude oil prices occurred when the United States imposed its quota system on oil imports and at that time Canadian oil in effect became subject to world price competition through delivery of offshore crude to Montreal. With the imposition of United States quotas and an over-abundant world crude oil supply, the expansionary phase for Canada's oil producing industry would have come to a near halt without the adoption of the National Oil Policy in 1961. The policy in the ensuing 1960's was directed towards increasing exports to the United States.

The Resource Base and Reserves of Oil. Canada's proved oil and liquid hydrocarbon reserves remaining at the end of 1972 were 9.7 billion barrels. These are scattered across the western provinces with the greatest concentration in Alberta. Inherently higher in cost than the resources of the major overseas exporting countries, Canadian oil has been developed over the past 25 years along lines consistent with United States practices in regard to acquisition of mineral rights, conservation practices, production regulation and pricing. Development of Western Canada oil has had a major regional and national economic impact and has contributed significantly to Canada's technical capability and material resources.

Potential "conventional" oil reserves as estimated by industry and government sources are large, about 100 billion barrels, but most are located in Canada's "frontier" areas: the Arctic and the offshore (Atlantic, Arctic, Pacific and Hudson Bay). Moreover, this potential is as yet almost entirely unrealized. The economic value of this resource potential will depend not only on actual productivity, but also on the economic attractiveness of these supplies in both the Canadian and possible export markets.

Additionally, it is estimated that there are some 300 billion barrels of potentially recoverable oil (bitumen) in the tar sands of Alberta provided the necessary extraction technology is developed. Commercial scale recovery operations have been in progress since 1967, reaching a reasonably high load factor of operation only during the last two years. The economic viability of this first operation remains to be determined, although it appears now that the plant's operation has reached an economic break-even point.

Federal Government Policies. The broad aim of federal oil policy has been to encourage a viable oil industry to provide for increasing use of natural resources on an economic basis. This objective has been pursued mainly by assisting the industry to maximize its market opportunities and also by offering some fiscal incentives, opening federal lands onshore and offshore to exploration and encouraging harmonious provincial policies.

The policy known as "The National Oil Policy" (NOP) was an attempt to achieve the resource development objective without excessive penalty to Canadian consumers. In the domestic market a balance was struck between imported and indigenous supply at the "Ottawa Valley Line". This was linked to a policy of expansion into export markets in the northern United States.

The objective of the NOP as established in 1961 has been exposed to periodic review and to date has been reaffirmed. For nearly a decade the policy functioned well under voluntary cooperation of industry. In 1970, a decline in the competitive strength of indigenous oil in Ontario markets necessitated introduction of mandatory controls on motor gasoline imports in order to support established NOP objectives.

The recent amendments to the National Energy Board Regulations made the exports of crude oil and equivalent hydrocarbons subject to licence. This will assure that oil exports do not exceed quantities surplus to reasonably foreseeable requirements for use in Canada. This action is consistent with the general policy of exporting only what is surplus to Canadian needs.

Although over the past few years Canada has become self-sufficient in petroleum requirements, imports have remained a vital source of supply to Quebec and the Atlantic Provinces. These areas lie at distances from our resources which so far have proved economically prohibitive. Although capable of producing all of its petroleum requirements, Canada supplies less of its own oil requirements from its domestic sources than does the United States, partly because of the greater distances in Canada between our resources and these important areas of consumption and because these distances are overland, thereby requiring pipelines rather than coastal tankers.

About half of Canada's petroleum requirements are now met from foreign sources compared with seventy-nine per cent in 1950. The present proportion

would be far greater if it were not for the operation of the national oil policy, which seeks to reserve Canadian markets west of the Ottawa Valley to oil of domestic origin.

The assumptions and postulates of this policy have been under continuing review. Among them, the particular assumption that security of supply does not impose a constraint on the formation of policy has come under intensive study because of recent international political events. The subject is of crucial importance for Canadian policy orientation, and merits continued study in the future. The principal elements of the problem are as follows:

Canada's dependence on foreign oil supplies is concentrated in the eastern part of the country, mainly the Atlantic Provinces and Quebec where the dependence is absolute. Eastern Canada thus enjoys the advantages of access to low cost overseas oil supplies but it also runs the risk, along with most other world petroleum markets, of having those supplies interrupted because of political and economic unrest in producing areas.

There need be no worldwide shortage of oil in the immediate future. There are huge reserves distributed about the world, totalling on the basis of proven reserves alone about thirty years of world consumption at current rates. The problem for importing countries lies in the fact that the largest and most important reserves are located within the territories of countries which suffer political instability of varying nature and degree. The major danger to continuity of supply is not that of physical destruction of facilities in the course of political upheavals, but rather the manipulation of control over large blocks of production for purposes of international politics or economic gains. In short, the developed western world is vulnerable to oil embargoes being imposed against them by oil-rich states. The far reaching and disruptive effects of political crises in oil areas were seen in 1956, 1967 and to a limited extent in 1970.

Canada, even though desirous of avoiding political involvement, may suffer along with other importing countries during such crises for the reason that the international oil companies, faced with an overall shortage, may be forced to reallocate the available supplies on a priority basis. This might involve a "rationing" system among all importers, leading, at the very least, to some undesirable price and quality effects.

Such a situation, involving a continuing threat to national economic strength, requires a carefully balanced response involving a realistic assessment of the risks involved and their weighing against the alternatives that may be available for the improvement of security. The alternatives range from arrangements for mutual support in times of supply crises to some arrangements which would require heavy pre-investment in supplies and/or equipment. There is also the possibility of a deliberate rearrangement of existing trading patterns.

While the physical danger of short-term interruption of Canada's imported oil supply needs to be kept under continuous review, there is the less obvious but more fundamental and long range possibility that imported supplies may not always be plentiful and/or cheap. The national oil policy assumed the ready availability of low cost foreign supplies, in fact it was this very characteristic which gave rise to the policy in the first place.

Nevertheless, a legitimate area of concern should be the complete dependence of Eastern Canada on imported supply which may very well become more expensive in the future, if not in actual shortage. There was a world surplus of oil from 1957 to 1970 and realized prices in the Middle East and the Caribbean declined very markedly. However, the pendulum is swinging the other way: increased demands from host countries for greater revenue and state participation; the demand for firmer prices, even at the cost of foregone production; the continued rapid increases in world oil demand; the re-examination of anti-pollution standards resulting in increased demand for low sulphur crude and products.

The two facets of imported oil supply discussed above, its vulnerability to temporary disruption and its transformation into a higher cost energy source, merit continuous study and watchfulness if oil policy is to remain adequate. These are questions related to the overall issue of balancing the advantages of encouraging the marketing of western Canadian indigenous oil in Eastern Canada against the alternative of importing.

The issue is further complicated by the excellent potential for oil in Canada's frontier areas (eastern offshore and Arctic). Discovery of large, economic reserves, which could occur at any time, could reduce discussion of the role of oil imports to the academic, or at least to short-term considerations. On the other hand, if discoveries are not large or if their economic viability in the Canadian market is in doubt, a number of new and difficult policy questions will be raised concerning the relative shares of imported and domestic oil.

Provincial Government Policies. The western provinces have given attention to a broad spectrum of oil exploration, production, transportation and marketing matters. Provinces have enforced conservation practices respecting the spacing of wells, elimination of waste and reduction of environmental pollution; have regulated production rates; have ensured safety of facilities, plants and pipelines; have passed judgement on the economic viability of field facilities, gas plants, secondary recovery projects; have tried to achieve optimum benefit from land lease sales, royalty rates and taxation regulations. Some special incentives and a royalty schedule based on production rates have been provided for economically marginal projects, e.g. Great Canadian Oil Sands. They have made reservoir studies of maximum efficient withdrawal rates and have made regulations regarding the safety and public protection aspects of all oil industry operations.

The Alberta Legislature in 1972 passed the Mineral Taxation Act. The Act provides for the assessment and taxation of the rights to the remaining recoverable crude oil other than from oil sands.

Under the new Natural Resources Revenue Plan the Government of Alberta replaced the existing royalty regulations relating to crude oil under the Mines and Minerals Act with new regulations. The new royalty schedule provides for exemptions from the taxation of the rights to crude oil for those to whom the new royalty schedule is applied. This is a one-time option whereby a holder of rights to crude oil under lease from the Crown may elect to pay the new royalty rates in lieu of payment of this taxation.

This tax and the option to elect the new royalty schedule in lieu of paying the tax is designed to extract more economic rent from the crude oil resources of the

province as these are being depleted. The Government of Alberta expects to increase revenues by about $80 million annually.

Jurisdiction Over the Oil Industry

Jurisdiction and Ownership of Oil and Gas. Subject to certain exceptions, the administration and operation of natural resource occurrences in the provinces are vested in the governments of the provinces. The federal government has jurisdiction over the resources in the Yukon and Northwest Territories and the offshore. Thus such matters as the disposition of mineral rights, conservation measures, mineral taxation, royalties, operating and safety rules are governed in general, by the laws and regulations of the province of occurrence or, in the Yukon and the Northwest Territories, by the laws and regulations of the federal government.

Matters relating to the leasing or sale of mineral rights are dependent on ownership, which, as distinct from jurisdiction, may be vested in individuals, corporations or the governments themselves.

The federal government owns several millions of acres of federal lands in the provinces. It issues leases covering mineral rights in the same way as any other owner and generally complies with provincial laws and regulations.

Provincial Regulation of the Oil and Gas Industries. The regulatory devices of the provinces include statutes and regulations dealing with conservation aimed primarily at the prevention of waste, the regulation of the spacing of wells and strict control over drilling and production practices. Each of the five oil producing provinces, excepting British Columbia, has specific legislation dealing with prorationing of production to market demand.

Jurisdiction Over Pipelines. Each of the five oil producing provinces has statutes dealing with the construction and operation of pipelines. The National Energy Board Act provides for regulating of pipelines "connecting a province with any other or others of the provinces, or extending beyond the limits of a province". As interprovincial or external pipelines must by necessity have some connection with local gathering lines there is a question of where provincial jurisdiction ends and federal jurisdiction begins.

Although constitutional and jurisdictional problems with respect to pipelines are generally the same for oil and gas, it may be noted that gas transmission companies typically are not integrated with production and distribution companies whereas, in contrast, there is considerable integration by the major oil companies of facilities for the production, transmission, refining and marketing of oil.

Offshore Oil. The Supreme Court of Canada in its West Coast Advisory Opinion handed down in November, 1967, was unanimous in finding entirely in favour of the Crown in right of Canada with respect to the resources of all the submerged lands lying offshore from the "ordinary low-water mark" and outside of "harbours, bays, estuaries and other similar inland waters". The principles forming the basis of this Opinion would appear to be substantially applicable to the east coast as well as to the west coast. There are, however, practical difficulties as regards application of provincial jurisdictional limits as indicated by the

Advisory Opinion of the Supreme Court—firstly, the geographic position of the low-water mark is shifting and uncertain; and secondly, our seacoasts are complicated by deep indentations, straits and inlets of various configurations, and the seaward limits of inland waters at the time a coastal province entered Union are not known.

On December 2, 1968, the Prime Minister made a comprehensive announcement in the House of Commons on the offshore situation, following this up with a further statement on March 4, 1969. In brief, mineral resource administration lines were established to clearly delineate the areas of federal and provincial interests in order to meet the practical requirements of mineral resource administration. The areas seaward of the lines would continue to be administered by the federal government, and those between the lines and the shore would be administered by the appropriate provincial government, which would receive all mineral resource revenues accruing therefrom. The Prime Minister further announced that the federal government was prepared to share with the provinces those mineral resource revenues accruing from the federally-administered areas off provincial coasts, that is, off the east and west coasts and in the Hudson Bay–Hudson Strait region.

Since the Prime Minister's announcements in December 1968 and March 1969, there have been many meetings and a great deal of correspondence between the federal government and provincial governments on the question of offshore mineral resources. At the moment, the main emphasis is on reaching a resolution of the offshore mineral rights problem as it relates to the east coast offshore. Federal-provincial discussions are continuing with the governments of the five east coast provinces, the Atlantic Provinces and Quebec, with a view to resolving the situation, if possible, without the necessity of the extensive litigation that would be required to legally resolve questions of ownership and jurisdiction.

The position of the federal government continues to be that administration must lie in the final analysis with Ottawa in view of the many factors and responsibilities involved of a national character, including: uniform and efficient management, standardized policies of resource management, optimum conservation practices, control of export arrangements, regional arrangements, establishment of Canadian criminal and civil law in the offshore, negotiations and agreements with foreign states, and so on. However, the federal government has expressed willingness to consider mutually acceptable arrangements whereby there would be input by adjacent provinces respecting the management of east coast offshore mineral resources.

THE NATURAL GAS INDUSTRY

Its Historical Development and Present Status

Natural gas had been produced since the 1880's in Eastern Canada, mainly in Ontario. However, the discovery of the Leduc oil field in Alberta in 1947 set the stage for discovery and development of large reserves of natural gas during the subsequent oil exploration boom and the construction of large-diameter transmission lines to carry natural gas to markets west and east of Alberta.

The Structure and Nature of the Natural Gas Industry. The natural gas industry in Canada consists of four separate sectors; production, gathering, transmission and distribution.

A large number of companies participate in the exploration for and production of natural gas in Canada. Many of these companies are relatively small and independent of large integrated and international oil companies. On the other hand, much of Canadian natural gas production is by Canadian affiliates of major international companies.

The two major gathering systems are the Alberta Gas Trunk Line Company Limited in Alberta and Westcoast Transmission Company Limited in British Columbia.

Three major transmission lines operate in Canada. Westcoast Transmission serves Canadian markets in British Columbia and exports gas to the Pacific Northwest area of the United States. Alberta Natural Gas Company is principally an exporter, supplying gas destined to markets in Northern and Central California. TransCanada PipeLines Limited serves Canadian markets east of Alberta as well as exporting to the United States Midwest, upper New York State and Vermont.

Distribution to end-users is performed by a number of companies which hold franchises to supply varying sizes of market areas. These companies range in size from public utility commissions which serve one city, such as Kingston, Ontario, to widespread operations such as those of Northern and Central Gas Corporation which serves areas of Manitoba, Ontario and Quebec.

Subject to certain exceptions, the administration and operation of natural resources in a province are vested in the government of the province. The federal government has jurisdiction over the resources in the Yukon, the Northwest Territories, the offshore and Canadian lands in the provinces. Ownership, however, as distinct from jurisdiction, may be in individuals, corporations and the governments themselves.

All interprovincial and international pipelines must apply to the National Energy Board for Certificates of Public Convenience and Necessity before proceeding with construction. Transmission pipelines which supply Canadian markets enjoy a degree of security superior to that of the usual business enterprise but in turn are subject to regulatory control. As a result their customers enjoy the economies of large scale single transmission systems.

The Supply and Demand Balance. The Canadian gas market is almost entirely supplied from domestic sources. The small remaining imports of natural gas from the United States will terminate in 1976.

Authorized exports of natural gas are presently at their highest level and no increases have been approved since 1970. All exports are to the United States.

The Production of Natural Gas. Natural gas is produced either from fields containing only natural gas or from fields in association with oil, either gas caps in oil reservoirs or gas in solution within the oil itself. Less than twenty per cent of the gas produced in Canada today is from fields associated with oil.

Gross production of gas increased from 58 billion cubic feet (Bcf) in 1945 to 2,850 Bcf in 1972. Significant volumes of gas are utilized or lost in one form

or other before supplies actually reach final consumers. Historically, the largest proportion of these "prior uses" was accounted for by gas which was reinjected into oil reservoirs for the maintenance of pressure in order to allow more efficient and greater volume of oil production, and also reinjected into gas fields to permit "cycling" operations for greater recovery of natural gas liquids. These uses, together with gas "flared", are deducted from "gross production" in order to give "net production" statistics. Net production of natural gas rose from 49 Bcf in 1945 to 2,460 Bcf in 1972.

NATURAL GAS SUPPLY AND DEMAND BALANCE

(*in billion cubic feet*)

	1955	*1965*	*1970*	*1972*	*Average Annual Per Cent Growth*
Marketable production	123	1,107	1,839	2,252	18.7
Imports	11	45	11	16	
Total supply	134	1,152	1,850	2,268	18.1
Domestic demand	124	631	1,044	1,256	14.5
Exports	11	404	780	1,012	30.4
Total demand	135	1,035	1,824	2,268	18.1

SOURCE: Statistics Canada.

Net production of gas is further reduced by significant volumes in gas processing plants. These plants remove natural gas liquids such as propanes, butanes and pentanes plus and certain impurities such as hydrogen sulphide, to yield a dry, "pipeline" quality gas. Certain volumes of gas are also used by the processing plants for their own fuel requirements and for operating field equipment of various kinds. After making the requisite allowances for all of these volumes, the remaining gas supplies are termed "marketable pipeline gas". Marketable pipeline gas production in Canada rose from 41 Bcf in 1945 to 2,250 Bcf in 1972.

By any of the measurements, gross, net or marketable, the growth in Canadian natural gas production over the 1945-1972 period was remarkably rapid. The development of Canadian natural gas production by province is given in the following table on the "gross" basis of measurement.

The Marketing of Natural Gas. In the past, natural gas was a by-product of oil production. It had to be gathered and marketed to meet conservation regulations. However, as technology in the use and in transportation of natural gas improved, demand for natural gas accelerated. Prior to the construction of long distance pipelines, consumption of natural gas in Canada was highly localized in the general areas of production, especially in Alberta. This province accounted for 83 per cent of total natural gas sales in 1945, out of a total of 49 Bcf. Local supplies in Ontario were responsible for the bulk of the rest of the sales, with minor amounts also sold in the areas adjoining the small New Brunswick gas fields.

Gross Production of Natural Gas

(*in billions of cubic feet*)

	1955	*1965*	*1970*	*1972*	*Average Annual Per Cent Growth*
New Brunswick	0.2	0.1	0.1	0.1	
Quebec			0.2	0.2	
Ontario	10.9	12.6	17.1	13.0	1.0
Saskatchewan	11.2	59.7	78.7	68.7	11.3
Alberta	163.6	1,281.3	2,184.3	2,329.1	16.9
British Columbia	0.2	171.1	342.8	428.4	
N.W.T.	0.2	0.6	0.9	12.1	
Canada	186.3	1,525.4	2,624.1	2,851.6	17.4

Source: Statistics Canada.

Consumption in Canada (including field and plant use) had risen to 369 Bcf by 1960 accounting by this time for 12 per cent of the total actual energy market. By 1972 gas consumption in Canada had reached 1,405 Bcf or 24 per cent of primary energy consumption. Thus, over the 27 year period, 1945 to 1972, Canadian natural gas consumption had increased almost thirtyfold.

With this increase in natural gas consumption also came a considerable shift in the use of natural gas. While there are variations in the patterns of natural gas use across the country, the industrial sector absorbed the largest part of the greatly increased volume of natural gas coming on the market in the past 27 years.

The following table shows the relative importance of demand for natural gas by sector of demand:

Net Sales of Natural Gas

(*Percentage*)

	1945 (*Estimated*)	*1955*	*1965*	*1970*	*1972*
Residential	50	38	33	26	23
Commercial	24	19	18	20	21
Industrial	26	43	49	54	56

Source: Statistics Canada, Gas Utilities.
1972 Estimate

The expansion of the natural gas industry, although dramatic, has not been an easy one. It suffered perhaps most from the necessity of finding markets far removed from the centres of production at a time shortly after conversion of these markets from coal to oil. In British Columbia this meant that an export market

was necessary to make gas supply an economic possibility. The domestic market in British Columbia could not have supported a pipeline system on its own for many years.

Eastward expansion suffered from similar circumstances. It was believed that the Montreal market and some export markets had to be added to augment the marketing area of Ontario in order to make the project viable. The inclusion of Montreal proved to be much less of a necessity than exports and when the oil policy line was established west of Montreal, natural gas in Montreal was left only marginally competitive.

During the 1950's the Federal Power Commission (FPC) in the United States was required by the U.S. Supreme Court to regulate wellhead prices of natural gas. The low prices set had the effect of artificially maintaining the by-product status of natural gas. The maintenance of low prices encouraged the expanded use of natural gas. At the same time, the FPC through import restrictions exerted downward pressure on the price of Canadian natural gas sold in the United States. In 1969 it became obvious that U.S. supply would not meet the greatly expanded U.S. demand much longer. Consequently, competition by U.S. companies for Canadian gas became more intense and resulted in some increases in wellhead prices paid in Canada.

Within Canada the delivered cost of natural gas has been influenced to a considerable degree by the distance between the natural gas producing areas in Western Canada and the main consuming areas in Ontario and Quebec.

Prices of coal and fuel oil have undergone rapid increases since 1970 while gas prices, based on longer contractual terms and subject to regulation, have remained relatively stable. This factor coupled with the use of gas for anti-pollution purposes has heightened the demand for natural gas.

The Field or Wellhead Price of Natural Gas. Gas is generally sold by producers at the wellhead or the field "gate" under a normal supply/demand relationship by arm's length bargaining between producer and purchaser. However, it might be noted that in some areas there is only one prospective gas purchaser. There has been to date little or no regulation of prices paid to natural gas producers in Canada.

In most cases producers own and operate field gathering systems and sell gas at the plant "gate" rather than at the wellhead. Such plants remove undesirable non-hydrocarbon gases as well as the heavier hydrocarbons prior to delivery to pipeline companies. The heavier hydrocarbons and in some cases sulphur products are recovered and marketed. Such plants are considered to be part of the producing system, and operate over a wide spectrum of profitability.

Most field purchase contracts in the past included an initial fixed price, plus price escalation of about ¼ cent per thousand cubic feet per year. Some contracts contain a "favoured nations" clause under which the purchaser guarantees to offer the producer the same terms and conditions as those negotiated in later contracts with other producers in the same field or some other specified area. Many contracts also provide for periodic renegotiation to reach a "fair market price", with provision for arbitration.

Most contracts between exporting companies and producers provide for price variations, related to ranges of the U.S./Canadian currency rate of exchange.

The wellhead price of gas has risen only moderately during the past decade. Recent negotiations in Alberta, however, have resulted in substantially higher prices. It is the stated objective of the Alberta government to bring about an increase in prices for gas to reflect its commodity value in the market, relative to other competing fuels.

The Resource Base and Reserves of Natural Gas. Major new reserves of natural gas were discovered in Western Canada following the Leduc oil discovery in 1947. The estimated remaining proved reserves of gas as of 31 December 1972 were 53 trillion cubic feet, 78 per cent in Alberta, 17 per cent in British Columbia and the remaining 5 per cent in other areas of Canada.

Industry and government sources estimate that there is a potential of some 700 trillion cubic feet of natural gas in Canada. Of these estimated ultimate recoverable gas reserves, about one-third may be contained in the Western Canada Sedimentary Basin extending from the Prairie Provinces to the Mackenzie Delta.

Federal Government Policies. The policy of Canada has been to license for export such quantities of natural gas as are deemed, after a hearing by the National Energy Board, to be surplus to the reasonably foreseeable requirements for use in Canada, if the export price to be charged for the gas to be exported is just and reasonable in relation to the public interest. Decisions of the Board to issue licences are subject to approval by the Governor-in-Council. At the present time, the only export market is the United States.

The history of the development of this policy is as follows:

In 1957 the government appointed a Royal Commission on Energy to enquire into all matters having to do with energy. This Commission, known as the Borden Commission, recommended in its reports of 1958 and 1959 that an independent judicial tribunal be established and charged with the responsibility, inter alia, of determining the exportable surplus of natural gas and of adjudging the terms of export contracts. In 1959 the government, acting upon this recommendation, created the National Energy Board under the Act of that name.

Over the years the Canadian gas industry has been shaped to a very large extent by the policy decisions of both the Canadian and United States governments. The Canadian government's policy objectives basic to this evolution of policy have been:

(a) to assure Canadian consumers of the availability of adequate natural gas supplies at economic prices,

(b) to encourage the development of our abundant natural resources,

(c) to encourage continued expansion of exploration by allowing the sale of surplus natural gas in export markets, thus improving Canada's international trade accounts under price conditions which

- (i) recover the appropriate share of the costs incurred;
- (ii) are not less than the price to Canadians for similar deliveries in the same area; and
- (iii) do not result in prices in the U.S. market area materially less than the least cost alternative for energy from indigenous sources, and

(d) to safeguard the national security, both in terms of physically available resources, and of capacities to provide and use them.

Under these policy objectives, in the period between 1960 and 1972, the quantity of gas consumed in Canada has almost quadrupled from some 370 billion cubic feet to some 1,400 billion cubic feet. Exports to the United States have increased from approximately 110 billion cubic feet in 1960 to over 1,000 billion cubic feet in 1972. Total exports of gas during the period exceeded 6 trillion cubic feet and produced revenue at the international border of over 1.7 billion dollars. Remaining proven reserves of natural gas in Canada were 53 trillion cubic feet at the end of 1972. These results have been achieved by extensive exploration, drilling and construction of gas plants and pipelines.

The development of the gas industry, particularly its major pipelines, has done much to meet the objectives of government policy, as shown by an examination of achievements to date.

Prior to the construction of the TransCanada line in 1957 and 1958, the natural gas reserves of Alberta were largely "locked-in" and the potential markets in Central Canada lacked the advantage of an abundant supply of natural gas. The same statements can be made in regard to British Columbia reserves and markets prior to the construction of Westcoast Transmission Co. pipeline. Thus the building of these two transmission lines achieved the second and a major part of the first objective of Canadian gas policy, namely, development of our gas resources and its availability to Canadians within economic reach of this additional energy source. There were other important ancillary benefits to the overall economy with particular regional significance.

The Westcoast line also began the achievement of the third objective, that of exporting surplus supplies, thus improving Canada's international trade accounts. This objective was also attained by subsequently approving exports by TransCanada to the United States Midwest commencing in 1960 and to Vermont commencing in 1965. An additional stimulus was provided by construction of the Alberta–California pipeline in 1961, thus allowing additional quantities of locked-in reserves to be sold in that market and in Montana.

The construction of the Great Lakes Transmission Co. line through the United States in 1967 and 1968, in addition to other significant advantages, did much towards achieving the fourth objective of security of supply for Central Canada by providing an alternate route from Western Canada.

Marketing problems emanate from the twin policies of attempting to obtain the highest possible price from the export market while maintaining the lowest possible price in Canada.

Provincial Government Policies. It is the stated objective of the Alberta government to bring about an increase in the price for gas to reflect its commodity value in the market relative to other fuels. To this end the present Alberta government has failed to approve additional gas removal permits since it came to office. It has also signified its intention to institute a system of rebates to Albertans to, in effect, keep the price of gas at lower price levels than otherwise. The province has also suggested that gas prices should be renegotiated more frequently, should have

more generous escalation provisions and that price arbitration should be done by Albertans, based on commodity value in the market.

With regard to the considerable gas potential existing in Canada's large offshore areas, the provinces have not yet accepted a revenue-sharing arrangement offered by the federal government following the Supreme Court of Canada opinion that the federal government has jurisdiction over offshore resources off the Pacific coast of Canada.

Jurisdiction Over the Gas Industry

Jurisdiction and Ownership of Gas. Subject to certain exceptions, the administration and operation of natural resources in the province are vested in the government of the province. The federal government has complete jurisdiction over the resources in the Yukon, Northwest Territories and the offshore. Thus such matters as the disposition of mineral rights, conservation measures, mineral taxation, royalties, operating and safety rules are governed in general, by the laws and regulations of the province of occurrence or, in the Yukon and the Northwest Territories and the offshore, by the laws and regulations of the federal government.

Matters relating to the leasing or sale of mineral rights are dependent on ownership, which, as distinct from jurisdiction, may be in individuals, corporations or the governments themselves.

Provincial Regulation of the Gas Industry. The regulatory devices of the provinces include statutes and regulations dealing with conservation aimed primarily at the prevention of waste, the regulation of the spacing of wells and strict control over drilling and production practices. Each of the five gas producing provinces, except British Columbia, has specific legislation dealing with prorationing of production to market demand. Problems with respect to sharing markets may arise when gas becomes commercially available from the federally-controlled area.

Three provinces (Alberta, Saskatchewan and Ontario) have statutory provision to prevent the removal of gas without a provincial permit. The federal government on the other hand has the power to regulate interprovincial and external trade.

Each of the provinces has comprehensive statutes under which it exercises detailed control over gas utility companies, including the prices of gas.

Three provinces have statutes providing for regulation of the price of gas at the wellhead, though no such regulation has been implemented.

Jurisdiction over Pipelines. Each of the five gas producing provinces has statutes dealing with the construction and operation of pipelines. The National Energy Board Act provides for regulating of pipelines "connecting a province with any other or others of the provinces, or extending beyond the limits of a province". As interprovincial or external pipelines must of necessity have some connection with local gathering lines there is a question of where provincial jurisdiction ends and federal jurisdiction begins.

Offshore Gas. The situation with regard to jurisdiction over the resources of the continental shelf is described in the earlier chapter on the oil industry.

Chapter 5

THE URANIUM AND THORIUM INDUSTRY

RESOURCES, PRODUCTION AND POTENTIAL

Historical Sketch. Canada's uranium industry was born in 1930 with the discovery of Eldorado Mining and Refining Limited's Port Radium mine in the Northwest Territories, which produced radium, then in large demand, as well as uranium, copper, silver and cobalt from pitchblende ore from 1933 to 1940. The industry's major development began in 1942, however, in response to a demand for virtually unlimited quantities of uranium for the military programs of the United States and Britain. Port Radium was reopened, the company, now Eldorado Nuclear Limited, was expropriated, and the staking and mining of all radioactive minerals was banned in the Territories and in a number of provinces. At the same time, a uranium exploration program was launched jointly by Eldorado and the Geological Survey of Canada.

In late 1947, however, the ban on private prospecting was lifted and various incentives were offered by the federal government in an effort to encourage exploration. By 1953 several large low-grade deposits of uranium were discovered, most of which were subsequently developed under a "Special Price Formula", and by 1959 twenty-three mines with nineteen treatment plants were in operation in five districts (Figure 1). In that year, these plants shipped 15,892 tons[1] of uranium oxide (U_3O_8)[2] in concentrates, valued at $331,143,043 and uranium ranked fourth in value among Canada's exports, following newsprint, wheat and lumber.

By 1959 it became evident to the United States and Britain that sufficient uranium had been contracted to fill their foreseeable requirements. Consequently, with but one exception, all options to purchase uranium beyond March 31, 1963 were dropped. To prevent a complete collapse of the industry, arrangements were made for the deferment of deliveries and the transfer of contracts, and the federal government encouraged producers to arrange further sales for peaceful purposes, on their own behalf. Despite these steps, the industry declined dramatically and, in an effort to retain a nucleus of production, the federal government established two successive uranium stockpiling programs under which a total of some 9,600 tons of U_3O_8 were accumulated at a cost of about $101 million.

[1] Short tons used throughout.
[2] 1 short ton $U_3O_8 = 770$ kgs. of uranium metal.

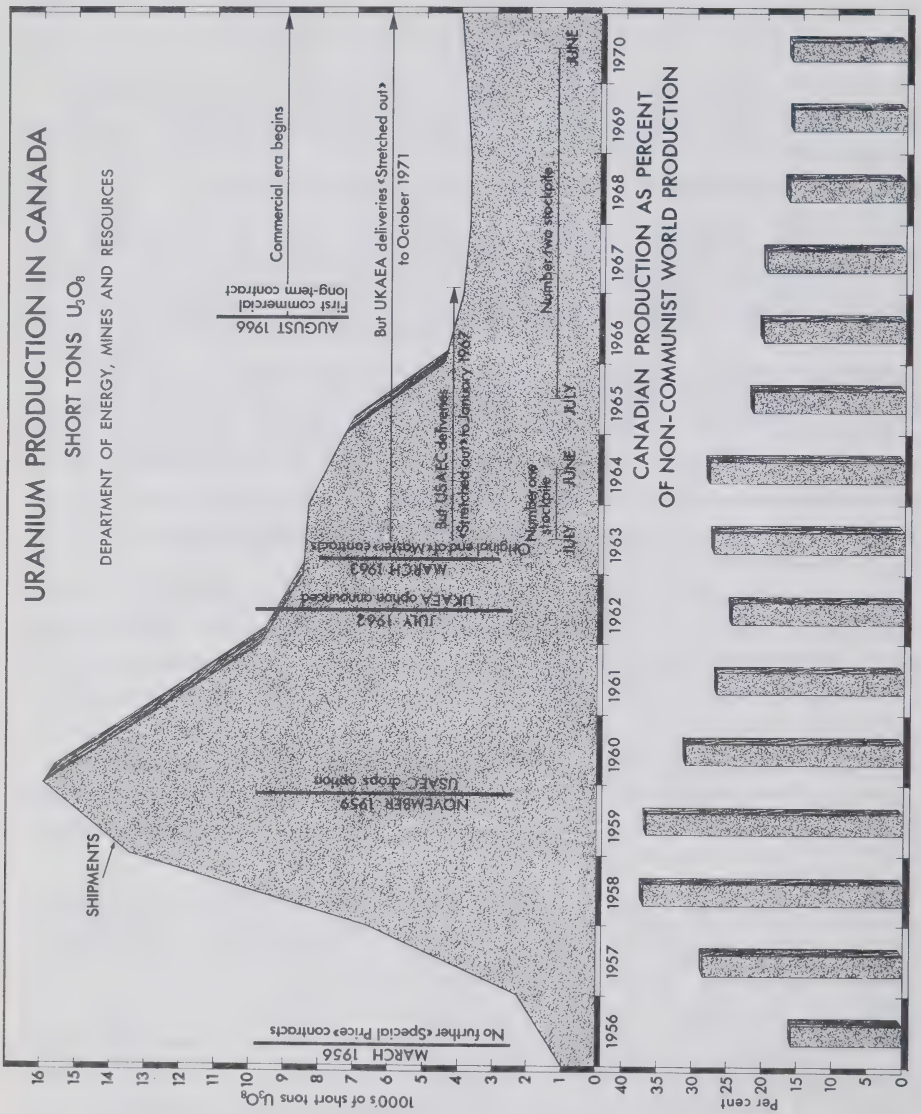
URANIUM PRODUCTION IN CANADA
SHORT TONS U_3O_8
DEPARTMENT OF ENERGY, MINES AND RESOURCES
SHIPMENTS
MARCH 1956
No further «Special Price» contracts
NOVEMBER 1959
USAEC drops option
JULY 1962
UKAEA option announced
MARCH 1963
Original end of «Master» contracts
But USAEC deliveries «Stretched out» to January 1967
Number one stockpile
JULY
JUNE
AUGUST 1966
First commercial long-term contract
Commercial era begins
But UKAEA deliveries «Stretched out» to October 1971
Number two stockpile
JULY
JUNE
1000's of short tons U_3O_8
CANADIAN PRODUCTION AS PERCENT OF NON-COMMUNIST WORLD PRODUCTION
Per cent
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970

Figure 1

TABLE 1

URANIUM MILLING PLANTS IN CANADA

Company	Location	Nominal Capacity (short tons of ore/day)
Active		
Denison Mines Limited	Elliot Lake, Ont.	6,000[a]
Eldorado Nuclear Limited	Eldorado, Sask.	1,800
Rio Algom Mines Limited—Quirke Mill	Elliot Lake, Ont.	4,500
Inactive[b]		
Can-Fed Resources Limited	Bancroft, Ont.	1,500
Preston Mines Limited	Elliot Lake, Ont.	3,000
Rio Algom Mines Limited—		
Nordic Mill	Elliot Lake, Ont.	3,700
Panel Mill	Elliot Lake, Ont.	3,000
Stanrock Uranium Mines Limited	Elliot Lake, Ont.	3,000[c]
Under Construction		
Gulf Minerals Canada Limited	Rabbit Lake, Sask.	2,000

[a]Present leaching capacity limited to about 4,400 tpd; mill expansion to 7,100 tpd scheduled for 1975.

[b]Capacities listed refer to capacities at time of closure; other past producing mills have been dismantled.

[c]Partly dismantled; recovery of uranium from mine water only, 1964 to 1970.

Present Status of the Industry. There are presently only three producers of uranium in Canada (Table 1). Rio Algom Mines Limited and Denison Mines Limited produce from quartz-pebble conglomerates in the Elliot Lake area of Ontario, and the Crown company, Eldorado Nuclear Limited, produces from pitchblende vein-type deposits near Uranium City, Saskatchewan; Eldorado also operates Canada's only uranium refinery at Port Hope, Ontario (Figure 2). Canadian uranium production in 1972 totalled 5,204 tons of U_3O_8, some 85 per cent of which came from the Elliot Lake district. Of the 5,204-ton total, producers shipped 4,898 tons, having an estimated value in excess of $60 million.

The industry is producing at a level considerably below its present capacity. Denison is operating its mine and mill at only about two thirds capacity. Rio Algom is operating only one of its three mills and one of its several mines, all in the Elliot Lake area. Eldorado has reduced its milling rate to about 50 per cent capacity. The available capacity of the three milling plants presently in operation is estimated at about 6,000 tons of U_3O_8 a year. All three producers have made plans for expansion and/or reactivation of their existing facilities and will proceed as markets permit. In addition, certain past producers are in a position to reactivate their facilities should suitable base-load contracts be obtained (Table 1).

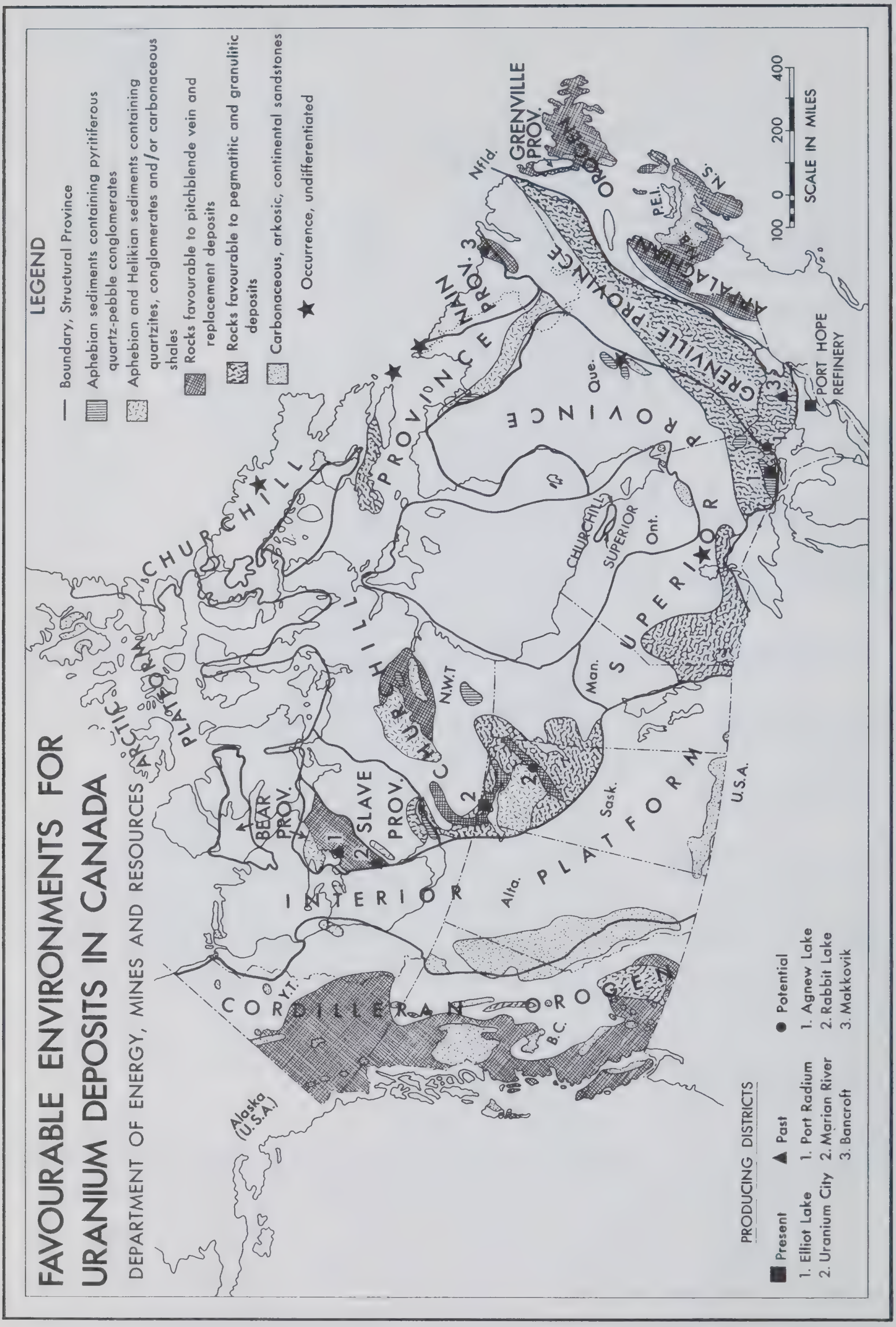
FAVOURABLE ENVIRONMENTS FOR URANIUM DEPOSITS IN CANADA
DEPARTMENT OF ENERGY, MINES AND RESOURCES
LEGEND
Boundary, Structural Province
Aphebian sediments containing pyritiferous quartz-pebble conglomerates
Aphebian and Helikian sediments containing quartzites, conglomerates and/or carbonaceous shales
Rocks favourable to pitchblende vein and replacement deposits
Rocks favourable to pegmatitic and granulitic deposits
Carbonaceous, arkosic, continental sandstones
Occurrence, undifferentiated
PRODUCING DISTRICTS
Present
Past
Potential
1. Elliot Lake
2. Uranium City
1. Port Radium
2. Marian River
3. Bancroft
1. Agnew Lake
2. Rabbit Lake
3. Makkovik
SCALE IN MILES
100 0 200 400
ARCTIC PLATFORM
CHURCHILL PROVINCE
INTERIOR PLATFORM
CORDILLERAN OROGEN
SUPERIOR PROVINCE
GRENVILLE PROVINCE
APPALACHIAN OROGEN
NAIN PROV.
GRENVILLE PROV.
BEAR PROV.
SLAVE PROV.
CHURCHILL
SUPERIOR
PORT HOPE REFINERY
Alaska (U.S.A.)
U.S.A.
Y.T.
N.W.T.
B.C.
Alta.
Sask.
Man.
Ont.
Que.
Nfld.
N.B.
N.S.
P.E.I.

Figure 2

Uranium exploration in Canada was essentially dormant from 1956 to 1966. Activity, which resumed in 1966 and reached a peak in 1969, resulted in several developments, two of which particularly affect Canada's production capability. First, was the development of Agnew Lake Mines Limited's Elliot Lake-type orebody, some 40 miles east of Elliot Lake (Figure 2). The deposit was initially discovered in the mid-1950's but never fully investigated. Although the property has now reached an advanced stage of underground development and a mill has been designed, operations have been suspended pending negotiation of a sales contract. Second, was the discovery in late 1968 of a pitchblende replacement-type deposit near Wollaston Lake, northern Saskatchewan, by Gulf Minerals Canada Limited. The deposit (an open-pit proposition) is being developed jointly by Gulf and Uranerzbergbau GmbH & Co. KG of West Germany, for production in 1975, at a rate of 2,000 tons of ore a day.

Should the industry's contemplated plans for expansion, reactivation and development be carried out, it could attain an annual productive capacity of 14,000 tons of U_3O_8 within five years. Expansion beyond this level will require the discovery and development of new low-cost reserves, the geological potential for which is considered excellent. Exploration toward this end is continuing but at a much lower level than that reached in 1969. The decline was due primarily to a number of economic factors, but also partly to some uncertainty posed by the federal government's announced intention to limit the degree of foreign ownership in the industry. An increase in exploration is not expected before the short-term market outlook improves and the new ownership legislation is promulgated.

Reserves and Resources of Uranium in Canada. Canada is divisible geologically into four major regions, the Canadian Shield, of Precambrian age, and the bordering, largely younger, Appalachian Orogen to the southeast, Interior Platform and Cordilleran Orogen to the west, and Arctic Platform to the north. The Canadian Shield is divisible into seven structural provinces which differ from one another tectonically and in radiometric ages (Fig. 2). All uranium production in Canada has been obtained from the Superior, Churchill, Bear, and Grenville provinces, and only from the southern and western parts of the Shield, although deposits as yet unmined and numerous uranium occurrences are known elsewhere.

Many types of uranium deposits occur in Canada. The most productive type comprises pyritiferous quartz-pebble conglomerates that occur in the basal part of the Huronian sedimentary succession in the Elliot Lake–Blind River area of Ontario. Pitchblende-bearing vein and replacement deposits have also been important and continue to be so, primarily in northern Saskatchewan and the Northwest Territories, and some production has come from pegmatitic deposits in the Bancroft area of Ontario.

To the end of 1972 some 118,500 tons of U_3O_8 have been produced in Canada of which 69 per cent has been from quartz-pebble conglomerate ores, 29 per cent from vein and replacement deposits and 2 per cent from pegmatitic deposits. Reasonably assured resources at up to $10 per pound U_3O_8 are estimated at 241,000 tons of U_3O_8 of which about 80 per cent are in conglomeratic ores; most of the remainder is in vein and replacement deposits (Table 2).

Various studies of uranium potential have been initiated in Canada, studies of Proterozoic basins of the Canadian Shield, supplementary geophysical investi-

gations by means of airborne gamma-ray spectrometry and geochemical testing of rock units and areas favourable to the occurrence of uranium deposits. Although short range predictions indicate that Early Proterozoic conglomeratic deposits have the greatest potential, longer range investigations indicate that regions adjacent to Proterozoic basins and much of Canada that is underlain by continental sediments of Devonian to Early Tertiary age also have potential.

TABLE 2

URANIUM RESERVES AND RESOURCES IN CANADA, 1972

Price Category ($/lb)	Reasonably Assured Resources (Reserves) (short tons U_3O_8)	Estimated Additional Resources (short tons U_3O_8)
Up to 10	241,000	247,000
10–15	158,000	284,000

Markets for Canadian Uranium. As of December 31, 1972 there was some 30,000 MW(e) of nuclear generating capacity installed in the world. By 1985 the non-Communist world's installed nuclear capacity may exceed 600,000 MW(e), necessitating an annual uranium requirement of some 145,000 tons of U_3O_8. Canada's annual requirements will be relatively small, reaching perhaps 4,000 tons of U_3O_8 a year in 1990, based on 31,000 MW(e) of installed nuclear capacity, all of the CANDU-type. In total, however, Canada's cumulative requirements to 2000 may approach 100,000 tons U_3O_8.

Prior to 1958, Eldorado handled all marketing of Canadian uranium. Since then, producers have been at liberty to negotiate their own sales, consistent with Canada's policy that Canadian uranium be used only for peaceful purposes. In this regard, the federal government will authorize forward commitments to supply existing or committed reactors for the average life of each reactor. Actual export, however, is limited to that sufficient to maintain the moving-five-year-requirement of the importing country; additional stockpiling by the importing country in Canada is not precluded.

Although several small commercial uranium sales were made from 1958 to 1964, Canada's first major long-term contract was not announced until August 1966. By December 1972, Canadian producers had committed over 73,000 tons of U_3O_8, almost 90 per cent of which was for export markets, primarily in Japan, West Germany, Britain and Spain. At the end of 1972, an estimated 9,500 tons had been delivered under these contracts.

Following the completion of the second uranium stockpiling program in 1970, the federal government announced that, in view of the continuing poor short-term marketing situation it would consider further assistance for established uranium mining communities. Subsequently, the federal government entered into an agreement with Denison to jointly stockpile some 6 million pounds of U_3O_8 from 1971 to 1974, the cost to be shared 76/24 by the federal government and Denison,

respectively. In November 1972, the entire joint venture stockpile and a portion of the general stockpile were sold under contract to Spain.

Until early 1967, Eldorado's refinery operation was connected primarily with the conversion of mine concentrates to orange oxide (UO_3) largely for export. More recently, the principal product has been natural, ceramic UO_2 powder, used to manufacture nuclear fuel for reactors of CANDU design. Other refined products have also been produced for both domestic and export markets including uranium metal and various alloys, and a variety of depleted and enriched uranium products. To meet expanding world markets for uranium hexafluoride (UF_6), Eldorado completed an addition to its refinery for the production of UF_6 in 1971. The company will be supplying its own major export sales in the form of UF_6 and, in addition, has negotiated contracts for conversion on a custom basis for utilities in the United States, Sweden and Japan.

Processing of Canadian Uranium Ores. One of the highlights of the development of the uranium industry was the important contribution made by Canadian technologists in developing a satisfactory ore-treatment process. The original method of gravity concentration, used at the Port Radium mine from 1933 to 1951, did not give good recovery. In fact, the tailings from the early operations were later recovered and reprocessed because of their high uranium content.

During the early years much important work was done in the Radioactivity Division of the Mines Branch, in Ottawa. A successful leaching method of uranium extraction was devised and put into use for the first time at Port Radium in 1952. Mines Branch specialists also developed a continuous sodium-carbonate leach process for Eldorado's Beaverlodge mill, which went into production in 1953. The flow sheet developed at the Mines Branch was an important contribution to the technology on the processing of uranium ores. It was eventually adopted, with some revisions, by all uranium-treatment plants in Canada.

The principal treatment processes used are: the leaching of uranium ore with sulphuric acid and recovery of the uranium from clear solution by ion exchange followed by precipitation; and leaching of the ore with hot solutions of sodium carbonates followed by precipitation with sodium hydroxide from clear solution.

In Canada's peak year of production, there were 19 uranium ore-treatment plants in operation. All but one of these produced uranium by acid leaching at atmospheric pressure, at temperatures below the boiling point of the leach solution and with sulphuric acid solutions of 5 per cent or less. Generally, the uranium-bearing solutions are purified and upgraded by an ion-exchange step, and following neutralization, ammonia is usually used to precipitate the uranium as ammonium diuranate. Only two of these plants are still operating, Denison's 6,000 ton-per-day mill and Rio Algom's 4,500 ton-per-day mill both at Elliot Lake (Figure 3).

Only one Canadian plant, Eldorado Nuclear Limited's Beaverlodge operation, was designed to use an alkaline leaching process. The pitchblende-bearing ore, which is relatively high in carbonate, is leached in a hot sodium carbonate/sodium bicarbonate solution which is oxidized by adding oxygen. The uranium is precipitated directly from the leach solution as sodium diuranate by the addition of sodium hydroxide.

Considerable investigative work has been done on a search for improved methods of treating Canadian uranium ores. The ores have not generally responded

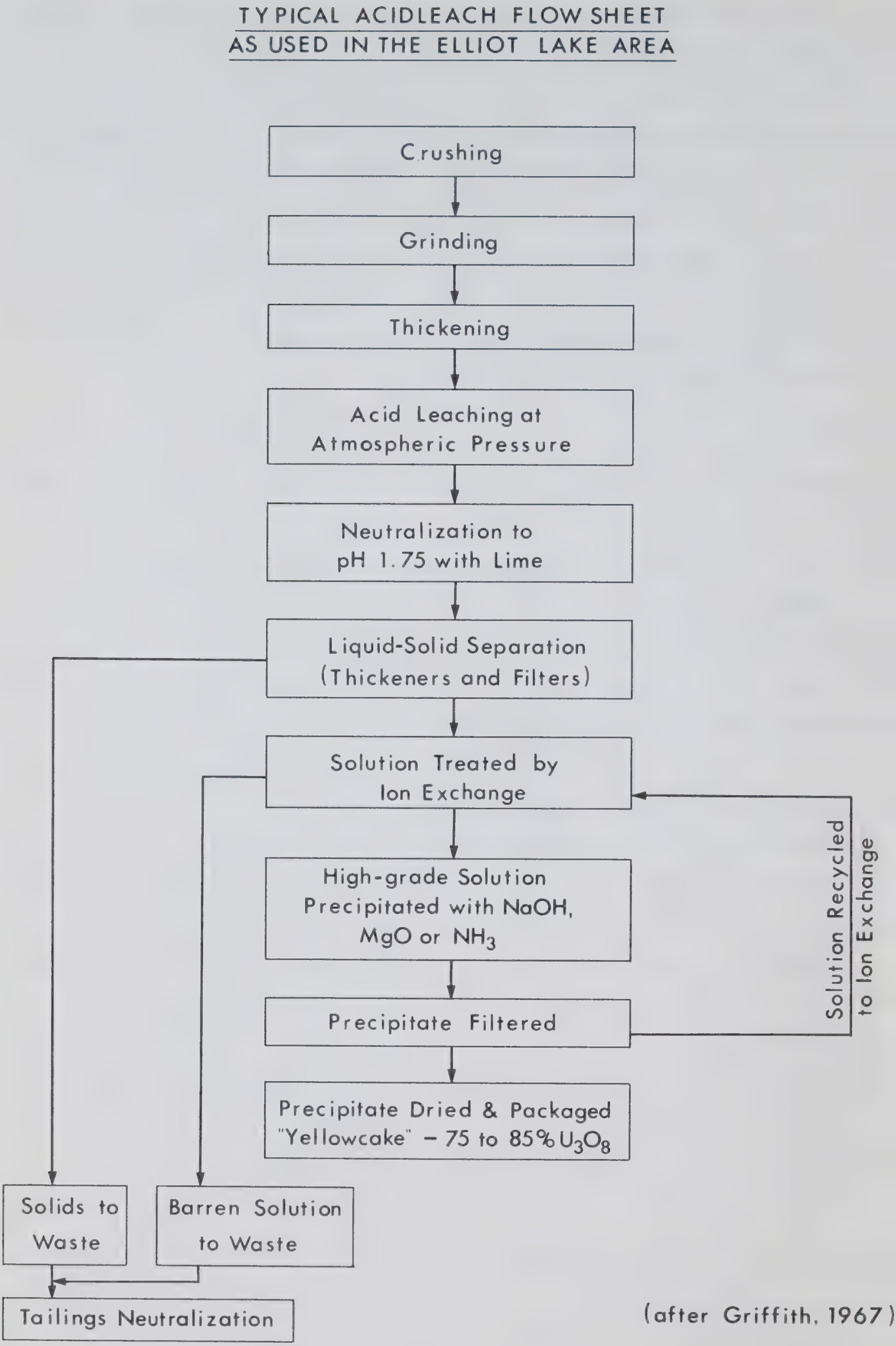
TYPICAL ACIDLEACH FLOW SHEET
AS USED IN THE ELLIOT LAKE AREA
Crushing
Grinding
Thickening
Acid Leaching at Atmospheric Pressure
Neutralization to pH 1.75 with Lime
Liquid-Solid Separation (Thickeners and Filters)
Solution Treated by Ion Exchange
High-grade Solution Precipitated with NaOH, MgO or NH_3
Precipitate Filtered
Precipitate Dried & Packaged "Yellowcake" – 75 to 85% U_3O_8
Solution Recycled to Ion Exchange
Solids to Waste
Barren Solution to Waste
Tailings Neutralization
(after Griffith, 1967)

Figure 3

to conventional beneficiation techniques such as froth-flotation, gravity-separation and magnetic-separation, although electronic sorting has been applied successfully at both Eldorado's Uranium City operation and at a plant in the Bancroft area.

For leaching the Elliot Lake ores, however, air-oxidation in pressure leaching and acid leaching with bacterially-oxidized solutions show considerable promise. In addition, laboratory tests have shown that percolation leaching techniques using bacterially-active solutions are capable of achieving 90 per cent uranium extraction in a few months.

Canadian investigators have also had considerable success with a solvent-in-pulp system using tertiary amine in a pulse-column contactor for recovery of uranium from leach solutions. Other studies using the same system have suggested a way to improve the efficiency of thorium and rare-earth separation as by-products from Elliot Lake ores and still other studies have indicated that high-purity UO_2 or UO_3 can be produced at the mine-site using solvent extraction techniques.

Uranium Refining in Canada. There is only one uranium refinery in Canada, that of Eldorado Nuclear Limited at Port Hope, Ontario. In past years the refinery's principal business has been the conversion of mine concentrates to orange oxide (UO_3). In line with developing requirements for reactor fuels, however, facilities have been added for the production of ceramic oxide (UO_2), both natural and enriched, uranium metal and high-density fuels, and recently for the production of uranium hexafluoride.

Briefly, the operations can be divided into four areas, UO_3 or orange oxide production, UO_2 or ceramic oxide production, uranium metal and vacuum casting, and uranium hexafluoride production.

The initial refining step consists basically of the digestion of mill concentrates with nitric acid and the upgrading of the uranium to nuclear purity using solvent extraction in a series of pulse columns. The uranyl nitrate stream so produced is then split; one part going to UO_3 for UF_6 or metal production, and the second to ceramic oxide production.

In the production of natural ceramic oxide powder, the uranyl nitrate solution is first precipitated with ammonium hydroxide to form ammonium diuranate. This is then filtered, washed and dried, reduced at about 540°C using dissociated ammonia, and finally stabilized by treatment with nitrogen and air. Enriched ceramic oxide is produced in much the same way.

The new uranium hexafluoride facility utilizes techniques developed at Eldorado in the 1950's which use vertical "moving-bed" reactors for the reduction of UO_3 to UO_2 and the hydrofluorination of the UO_2 to UF_4. Pulverized UF_4 is then fed to a primary flame reactor along with fluorine gas, and the resulting UF_6 stream is collected in cold traps prior to movement to shipping containers. The capacity of the UF_6 plant is now 2,750 tons of uranium a year; however, this will be expanded to 5,000 tons per year, perhaps by 1974, to bring UF_6 production in line with present UO_3 production capability.

In the fourth area of production, uranium metal is produced in the form of direct-cast ingots, by the thermite reduction of UF_4 with magnesium metal. Techniques have also been developed for the production of uranium carbide,

uranium silicide, enriched uranium-aluminum alloys and enriched uranium-zirconium alloys. Of further interest is Eldorado's production of depleted-uranium metal castings for radiation shielding and counterweights, and its design program for the manufacture of casks for the transport of spent nuclear fuel.

Thorium Potential in Canada. Thorium is closely associated mineralogically with both conglomeratic and pegmatitic uranium ores in Canada. Although thorium oxide to uranium oxide (ThO_2:U_3O_8) ratios are quite variable in both cases, those associated with present and past producing deposits are generally less than 1.0. Uraniferous conglomerates in the Agnew Lake area, however, have ThO_2:U_3O_8 ratios in the order of 2.0 to 3.0. Recent data suggest that reasonably assured resources of ThO_2, associated with uranium reserves in the $10 a pound U_3O_8 category (Table 2), conservatively exceed 100,000 tons of ThO_2.

In response to a demand for various industrial uses, thorium concentrates were produced as a by-product of Rio Algom's Elliot Lake uranium operations from 1959 to 1968. The product was in the form of a thorium sulphate, grading from 35 to 40 per cent ThO_2, and was shipped primarily to Thorium Limited in Britain. Small quantities were refined by Rio Algom to metallurgical grade ThO_2 (99.8% ThO_2) for Dominion Magnesium Limited, Haley, Ontario, which produces refined thorium metal, pellets and powder.

Consequently, with significant reserves of thorium readily recoverable as a low-cost by-product of uranium operations, Canada's uranium industry is capable of meeting a major portion of the expected future demand for thorium as a nuclear fuel.

Summary. Canada's uranium industry is in an excellent position to place prominently in future world uranium supply. Current production of uranium is some two thirds below short-term capability, and less than one third of Canada's known low-cost reserves are committed. Moreover, large areas of Canada are geologically favourable for uranium, and many are relatively unexplored. A leading supplier of refined uranium products, Canada is also potentially a major supplier of low-cost thorium. Indeed, with over 25 years of operating experience, and backed by extensive programs of research and development, Canada's uranium industry has developed considerable expertise. It is thus in a position to rapidly expand to exploit new discoveries that will undoubtedly be made in line with increasing demand.

Chapter 6

POLICY STATEMENTS

Statement by Hon. George Hees

1 February 1961

As the House is aware, the Government has been giving active consideration to the situation of the oil industry in Canada for some time. It has had the benefit of a constructive report from the Royal Commission on Energy and the National Energy Board has studied intensively the changing conditions which have characterized the period since the Commission reported.

I wish to inform the House that the Government has decided upon a national oil policy which is, briefly, to achieve target levels of production of oil, including natural gas liquids, which will be set from time to time, and which will be designed to reach approximately 800,000 barrels a day in 1963. This objective for 1963 can be achieved by the industry on an economically sound basis, and will be approximately as high as the figure which would be achieved if the Montreal pipeline were to be constructed.

The production target level for the first part of this period will be an average of 640,000 barrels a day for the year 1961, with a level of not less than 625,000 barrels a day to be attained by mid-year. This compares with an average production of 550,000 barrels a day in 1960.

These targets are to be reached by increased use of Canadian oil in domestic markets, west of the Ottawa Valley, and by some expansion of export sales largely in existing markets which can be reached through established pipelines.

The growth in domestic use is predicated in particular on substituting in Ontario markets west of the Ottawa Valley, products refined from Canadian crude for those now supplied from foreign crude. This will require in Ontario the displacement of the present small imports of crude, and a progressive reduction in imports of foreign products and transfers of products refined from foreign crudes in Montreal. Refining capacity in Ontario will have to be increased over the period so that by 1963 capacity is sufficient to enable the Ontario market, west of the Ottawa Valley, to be supplied substantially from Canadian crudes.

The Government program for expanded production of oil will be on a voluntary basis, but importers of crude and petroleum products will be required to report their imports monthly from January 1, 1961, in order to permit the National Energy Board to continue to assess the situation.

The increase in production of Canadian oil reflected in these target levels will of course require a sincere effort and full cooperation by all segments of the industry. The Government desires that this effort and cooperation will be forthcoming without formal regulation.

The Government has instructed the National Energy Board to evaluate the contribution of individual companies to the general efforts of the industry, as well as to report periodically on the progress of the program. If this progress suggests that voluntary efforts are not producing the results anticipated, then the Government will take whatever further steps the circumstances may require to ensure the success of its policy, including the proclamation of Section 87 of the National Energy Board Act, which provides for the regulation of imports and exports of oil.

In developing its policy, the Government has full regard to the interests of other countries which might be affected by its decisions. Its present program is designed to achieve the national objectives with the least possible disruption of normal trade patterns.

The increase in exports which is integral to the Government's program is wholly consistent with the growth of sales of Canadian oil contemplated when exemption from United States oil import controls was established, under which Canadian oil is relatively free to move into the United States by overland means of transportation.

The progressive displacement of imported crudes and products in the Ontario market is considered to be fully consistent with the public announcement of the Government of Venezuela that it considers that its oils should not reach these markets in the interior of Canada.

The United States Government has been made aware of the Canadian Government's plans in view of the close connections between the oil economies of the two countries. Other interested governments are being informed today of the contents of the announcement which I have just made.

Statement of NATIONAL POWER POLICY

by Hon. Mitchell Sharp
Minister of Trade and Commerce

October 8, 1963

I wish today to announce, on behalf of the Government, a national power policy. I do not think that I have to emphasize the vital role the power industry is playing and must continue to play in the development of our nation.

The story of the electric power industry of today is one of constant evolution as it strives successfully to reduce costs. Canada must provide the climate in which we can take advantage of these technical breakthroughs. Our policy places particular emphasis on

(a) the desirability of Canada taking fullest advantage of the evolutionary changes that have taken place in the nature of the power industry, including technological improvements in generating and transmission facilities, and the reduced costs of power associated with these;

(b) the provision of abundant supplies of electrical energy to consumers throughout Canada at the lowest possible cost to encourage and accelerate economic development and growth;

(c) the need for Canada to have a flexible export policy which, *inter alia,* would permit the export of large blocks of power to the United States for a relatively long period of years to assist in the immediate development of certain large-scale Canadian power projects, particularly undeveloped hydro resources which might not be viable in the near future unless provision were made for the marketing in the United States of a significant portion of their output; and

(d) the strengthening of our balance of payments position through the export of power surplus to our own needs.

The policy now being announced reflects important changes which have taken place in the circumstances affecting export of power. The Government is fully aware of the body of public opinion that has been opposed to export of power, in the first instance because of events which occurred over fifty years ago.

The National Energy Board Act now provides that all exports of power must be licensed by the National Energy Board with the approval of the Governor in Council. Licences may not be issued for a term in excess of 25 years. The National Energy Board is required to certify that the power to be exported does not exceed the surplus remaining after due allowance has been made for the reasonably foreseeable requirements for use in Canada—this has been interpreted to mean surplus to Canadian requirements which can be supplied economically from the generating facilities producing the power for export.

Further, the Board must satisfy itself that the export price of the power is just and reasonable in relation to the public interest.

From 1907 until the coming into force in 1959 of the National Energy Board Act, the export of power was subject to licence under the Exportation of Power and Fluids and Importation of Gas Act. By regulation under that Act, the term of a licence was limited to one year. This was intended to prevent permanent alienation of Canadian power capacity which, though surplus when installed, would be required in Canada as time went on. It was realized that, if an industry or a community in the United States became dependent on a Canadian power supply, it would be difficult, if not impossible, to withdraw that supply.

Such difficulties as have occurred in respect of the recapture of power exports arose, in part, because over 50 years ago long-term contracts (up to 85 years) were made by Canadian power producers with specific industries in the United States. The contracts contained no provisions for the repatriation of the power. The Canadian supplier, in effect, had taken on within the United States the responsibility of a public utility to maintain continuity of supply for its customers. As a result, the protection of the one-year limitation on licences was illusory.

The nature of the power industry today is very different from what it was in 1907 and in most of the intervening years. It is now unusual for the capacity of a large, modern electric plant to be dedicated to a single industry or for a large utility to be dependent on one source of power supply. We are entering the era of large private and public electrical utilities, interlinked with high voltage lines, and operated pursuant to interconnection agreements designed to take advantage of the new technological improvements and the economies of scale.

A public utility, whether in Canada or the United States, now takes it as a matter of course that it must contract for or install capacity to replace a portion of its total power supply, when the contract covering that portion runs out. The old aphorism that an export sale, once established, cannot be terminated without hardship in the export market and danger of international friction, is no longer valid if the export contract is made with a public utility in the United States under reasonable terms and conditions.

When the National Energy Board Act came into effect in 1959, power export licences which had been issued under the Exportation of Power and Fluids and Importation of Gas Act were continued in effect for some time, so that the Board might apply to each case (with minor exceptions) the procedure of application, public hearing, detailed analysis and recommendation to the Governor in Council.

In 1959, actual total exports, as distinguished from licensed authorizations, were 4,582 million kilowatt hours. In 1962, export had declined to 80 per cent of the 1959 total.

In 1962, Canada produced 117 billion kilowatt hours, including 11.4 per cent from thermoelectric plants. Of the total production, only 0.47 per cent was exported as firm energy and 2.8 per cent as interruptible energy. Of the latter, 86 per cent was interchanged with United States utilities, having been returned to Canada at the same time over other circuits, or over the same circuits at other times.

In the light of the circumstances I have outlined, the Government has decided to develop and carry forward effective policies embracing two essential concepts:

> first, encouraging development of large low-cost power sources and the distribution of the benefits thereof as widely as possible through interconnection between power systems within Canada; second, encouraging power exports and interconnections between Canadian and United States power systems where such induce early development of Canadian power resources.

More specifically, our policy is as follows:

The Government, having due regard to the rights of the provinces with respect to the development and distribution of power and keeping in mind its own responsibilities in this field, desires to encourage interconnection agreements and maximum utilization of intertie facilities between electrical systems, both publicly- and privately-owned.

The Government, in cooperation with the provinces, has already undertaken studies to investigate the possibility of interconnecting power systems across the country. It realizes that

the complete interconnection may not be economically feasible for some years to come. Nevertheless, it would appear that by establishment of interconnection facilities between utilities in adjacent regions wherever practical, a national system might be developed by a succession of stages, each valuable in itself.

The Government believes that it would be beneficial to Canada and to the United States, and not prejudicial to the national interest to encourage interconnection agreements and interties between utilities in the respective countries in cases where the interconnection agreements suitably protect the Canadian interest.

In cases in which Canadian utilities enter into appropriate interconnection agreements with United States utilities, the Government will be prepared, upon recommendation of the National Energy Board, to give favourable consideration to the authorization of export of power to United States utilities for purposes including the following:

(i) to provide standby service in the case of emergencies; thus making possible the reduction of reserve generating capacity otherwise required by the utilities;

(ii) to provide for economy flows between plants or systems;

(iii) to provide for sales of surplus interruptible energy;

(iv) to provide for exchange of power and energy to take advantage of load, watershed or other diversities;

(v) to provide for exports of firm power for limited periods to make possible the step by step construction of the most economical generating facilities on either side of the boundary.

The Government also believes that it would be in the national interest, in suitable cases, to license the export of large blocks of firm power to United States utilities to permit the development of large-scale remote hydro or other power projects which would not be viable unless supported by the export for long periods of a significant proportion of the power generated. The National Energy Board Act permits such exports for periods of up to 25 years. Provision would have to be made for the recapture of such exported power over a period of years, in stages commensurate with the need or ability of the Canadian market to absorb it, and upon notice adequate to enable the importing utility to arrange for replacements. The provisions of the National Energy Board Act would, of course, apply to any case of this nature, as to any export of power.

The Government will, upon recommendation of the National Energy Board, continue to authorize the export of relatively small amounts of power and energy to border areas in the United States where, for geographical reasons, Canada is the economic source of supply.

Statement by Right Hon. L. B. Pearson

URANIUM CONDITIONS APPLICABLE TO GRANTING OF EXPORTS PERMITS—STOCKPILING PROGRAM

3 June 1965

The Government has been reviewing its policy with respect to the export of uranium.

World requirements for uranium for peaceful purposes will increase very greatly in the years to come. Canada holds a substantial portion of the known uranium reserves of the world and in the future may well be the largest single supplier for the rest of the world. It is vital that the Canadian industry be in the best possible position to take advantage of expanding markets for the peaceful uses of this commodity.

As one part of its policy to promote the use of Canadian uranium for peaceful purposes the Government has decided that export permits will be granted, or commitments to issue export permits will be given, with respect to sales of uranium covered by contracts entered into from now on, only if the uranium is to be used for peaceful purposes. Before such sales to any destination are authorized, the Government will require an agreement with the govern-

ment of the importing country to ensure with appropriate verification and control, that the uranium is to be used for peaceful purposes only.

Canada has been a member of the International Atomic Energy Agency since its inception and successive governments have vigorously supported the principle of safeguards on uranium sales. This policy is a fundamental part of Canada's general policy to work internationally to avoid the proliferation of nuclear weapons.

As to the commercial aspects of the policy, two general principles will apply, designed to facilitate exports and to ensure that the requirements of both export and domestic consumers are met in an orderly way.

First, the Government recognizes that countries constructing or planning to construct nuclear reactors will wish to make long-term arrangements for fuel supply. Accordingly, the Government will be prepared to authorize forward commitments by Canadian producers to supply reactors which are already in operation, under construction, or committed for construction in other countries for the average anticipated life of each reactor, generally calculated for amortization purposes to be 30 years.

Second, and in addition, the Government will be prepared to authorize the export for periods of up to five years of reasonable quantities of uranium for the accumulation of stocks in the importing country.

Within the terms of the policy I have outlined, the Canadian Government will actively encourage and assist the Canadian uranium industry in seeking export markets. The commercial aspects of the policy will, of course, be reviewed from time to time in the light of changing conditions.

Finally, in order to avoid any reduction in the current level of employment and production in the industry in Canada, the Government will purchase uranium for stockpiling to the extent that current sales prove insufficient to achieve this objective during the next five years. These purchases will be made at a price of $4.90 per pound of uranium oxide. Purchases will be made only from companies which have previously produced uranium and will be limited, in the case of each company willing to sell at $4.90, to the amount necessary to maintain an appropriate minimum level of employment and production for that company.

As soon as the details of the stockpiling program, including arrangements for eventual disposal, have been discussed with the uranium industry and decided upon they will be announced to the House and Parliament will be asked to approve the necessary expenditure for the current fiscal year.

Statement on CANADIAN URANIUM POLICY

by Hon. Otto E. Lang
Minister of Energy, Mines and Resources

June 19, 1969

I should like to inform the House of the government's policy with respect to future sales of uranium to other countries.

On June 3, 1965, Prime Minister Pearson outlined to this House a policy regarding uranium exports which provided for such exports under safeguards to ensure that the uranium was used only for peaceful purposes, and which also provided for the stockpiling of uranium to enable operation of Canadian uranium mines to be continued while markets developed for this material.

Many significant changes have taken place since 1965 in the world uranium market. There is a growing world requirement in relation to available supply and a demand for long-term contracts. The increasing dependence on uranium fuel for future electrical power generation is providing an incentive for many countries to become concerned with uranium activities in other countries. At the same time the recent signature by many countries of the Non-Proliferation Treaty will, we hope and believe, curtail the spread of nuclear armaments.

These developments will have an impact on the Canadian uranium industry. Accordingly the government is now setting out its uranium policy in greater detail to ensure that full account is taken of the Canadian public interest in these new circumstances.

The basis of Canada's uranium policy is stated in the preamble to the Atomic Energy Control Act, namely that "it is essential in the national interest to make provision for the control and supervision of the development, application, and use of atomic energy, and to enable Canada to participate effectively in measures of international control of atomic energy which may hereafter be agreed upon".

To protect the national interest in the different circumstances which now face us we will henceforth require that all contracts covering the export of uranium or thorium be examined and approved by the appropriate federal agency before any application for an export permit is considered. The examination will cover all aspects and implications of the contract such as nuclear safeguards, the relationship between contracting parties, reserves, rate of exploitation, domestic requirements, domestic processing facilities, and selling and pricing policy. Approval will not normally be given to contracts of more than ten years' duration unless provision is made for renegotiation of price.

Once an export contract is approved, export permits covering the actual shipment of uranium or thorium may be issued annually provided that the conditions of the contract have been maintained. Approval will be granted only for the supply of uranium and thorium for peaceful purposes to customers in countries with which Canada has completed a safeguards agreement, or following the coming into effect of the Non-Proliferation Treaty, with customers in countries which have concluded the necessary safeguards agreement with the International Atomic Energy Agency.

Canada will permit stockpiling of Canadian uranium in foreign countries to meet the succeeding five-year requirements of each country to fuel existing or committed nuclear reactors. Additional stockpiling in Canada will not be precluded, but actual export shipment will be limited to a moving five-year requirement of the foreign country. The shipment of small quantities of materials for atomic energy research projects will continue to be permitted without safeguards arrangements.

We will continue to require that all persons engaged in uranium or thorium mining in Canada be incorporated under federal or provincial legislation, that they operate under licence from the Atomic Energy Control Board and that they provide information as required under the regulations of the Board.

The government believes that the administration of Canada's uranium policy in this manner, with regulations such as the foregoing, will enable the Canadian primary and secondary uranium industry to grow and take advantage of its opportunities in the world uranium market.

In the implementation and administration of these national policies, the federal government will maintain close contact with provincial governments on matters of common concern with respect to the uranium industry.

CONTROL OF FOREIGN OWNERSHIP OF CANADIAN URANIUM PROPERTIES AND FACILITIES

1 September 1970

Honourable J. J. Greene, Minister of Energy, Mines and Resources, announced today in Ottawa that a careful study had been completed of regulations proposed to be issued by Government in accord with policy statements made by him, on behalf of the Government of Canada, in the House of Commons on March 19th 1970, and May 5th 1970, concerning questions of foreign ownership relating to investment and participation in the uranium industry in Canada.

"It was proposed", the Minister said, "to bring in to force regulations under the Atomic Energy Control Act for the carrying out of Government policy with respect to the control of foreign ownership of Canadian uranium properties and facilities, but legal counsel now advise that some of the provisions which will be required by Government will necessitate legislation rather than regulations. Accordingly, the Government is preparing legislation to be introduced to Parliament during the forthcoming session, but it will take some additional time for this legislation to be made ready".

Because it was believed that the effective regulations would be completed by late summer, the Government had not intended to rule on applications made by various companies for clarification of their status, on the basis that the regulations, when issued, would clarify most if not all circumstances. In view of the continuing postponement and the decision to proceed with legislation, the Government has decided to act on behalf of applicants in two categories so as not to delay further decisions which will affect their exploration and development programs and planning in 1970 and 1971.

The first of these categories involves cases in which, under an executed and binding legal agreement an obligation had arisen prior to March 2nd 1970 for the transfer of a beneficial interest in a uranium property in Canada from one party to another. These agreements will be allowed to be carried out by the parties according to their terms. The second category concerns transfers from a foreign owner of an interest in uranium mineral properties and rights in good standing on March 2nd 1970, where it can be shown to the satisfaction of the Minister of Energy, Mines and Resources that negotiations for such transfer had commenced prior to March 2nd 1970, and had reached a firm stage of written agreement between the parties prior to March 2nd 1970 on the major terms of their arrangements. Parties in these circumstances will be permitted to conclude their legal documentation on or before December 31st 1970, and on so doing will be allowed to carry out their agreement according to its terms.

On the basis of the rules set out under the categories mentioned above, which will be provided for in the proposed legislation, the Government of Canada will advise Brinex, Consolidated Canadian Faraday Corp., Gulf Minerals Company and Kerr-McGee Corp., that no exception will be taken to their applications for transfers of interests in uranium properties in Canada to foreign owners. The transfers will, however, be required to be carried out according to the terms of legal agreements in existence on March 2nd 1970, or alternatively, according to terms not inconsistent with those entered into in writing by the parties as evidencing their intent and signed prior to March 2nd 1970.

The Minister also announced that following transfer of title permitted under the two aforementioned categories, no further transfer of interest would be permitted without the approval of the Government of Canada or until such time as the legislation proposed to be introduced to Parliament is enacted into law, after which, any further transfer shall be in accordance with such legislation.

The Minister further advised that nothing contained in his statement was intended in any way to derogate from the requirements of the Atomic Energy Control Act, and the regulations made thereunder and in force at this time. He further stated that the interest of foreign owners in uranium properties in Canada, and in the production of uranium ore therefrom, is required to be held in the form of Canadian incorporated companies and that the sale of products of production would be by a Canadian company or companies in such manner that the full profit potential of the sale will accrue in Canada.

If there are persons who have not made application for clarification of their status under the previous ruling, who believe that they fall within the two categories under which transfers will be exempted as explained here, then such applications should be made immediately, Mr. Greene stated.

Statement on the EXPORT OF CRUDE OIL

by Hon. Donald S. Macdonald
Minister of Energy, Mines and Resources

15 February 1973

I wish to advise the Committee that the Governor in Council has today approved amendments to regulations made under Part VI of the National Energy Board Act which have the effect of bringing under licence the export of crude oil and equivalent hydrocarbons, but not refined oil products, effective March 1, 1973. Copies of these amendments are available from the Clerk of this committee.

This action has been taken on the recommendation of the National Energy Board and after discussions which I have held with provincial ministers, and industry. Today's amendments will ensure that oil exports do not exceed quantities surplus to reasonably foreseeable requirements for use in Canada.

I need hardly remind members that it is long-established national policy to export only those quantities of energy which are clearly surplus to our domestic requirements.

In regard to oil, export licensing under the Exportation of Power and Fluids and Importation of Gas Act was in force until 1959. This licensing was terminated on the recommendation of the Royal Commission on Energy which concluded that western Canadian oil reserves were at that time more than adequate to supply foreseeable domestic and export requirements.

The power to control exports and imports of oil was however embodied in Part VI of the National Energy Board Act which came into effect in 1959 but, with regard to oil, the licensing provision was subject to later proclamation. Such a proclamation was made in May 1970 but the attendant regulations excluded oil other than imported motor gasoline.

The past fourteen years have seen rapid growth in our oil exports, almost all of which go to the United States and are mostly in the form of refinery raw material. This export growth has made an important contribution to the health of the Canadian oil producing industry and to our national prosperity.

However, recent levels of export demand for our oil have been such as to strain the capacity of our oil production and transportation systems and to threaten the continuity of supply of Canadian oil to domestic refiners dependent on such supply. Moreover, recent and prospective export-demand growth is such as to require continuous monitoring of the extent to which oil production will be available in quantities surplus to reasonably foreseeable requirements for use in Canada. In March there may be a transient problem of supply adequacy which we must be prepared to deal with, but it is now clear that the determination of exportable surplus of oil requires continuous scrutiny.

It is in these circumstances the present measures are being taken. They of course represent an important change in the mode of implementation of our national oil policy.

Today's amendments are interim in nature. The National Energy Board will shortly hold a public hearing in order to provide opportunity for interested parties to be heard as to the appropriate methods for protecting the public interest in respect of oil exports over the longer term. After such hearing, the National Energy Board will report its findings and recommendations to the Governor in Council and the regulations will be amended to the extent appropriate after opportunity to consider these matters.

Appointments to NATIONAL ADVISORY COMMITTEE ON NORTHERN PIPELINE FINANCING

March 29, 1973

Fifteen members were named today to the newly established National Advisory Committee on Northern Pipeline Financing by Energy, Mines and Resources Minister Donald S. Macdonald. The committee has been formed to advise the federal government on the financial and economic impact of Canadian northern pipeline development. Twelve of the members are from the financial sector and three from the federal government.

Appointed to the committee from the financial community are: Dr. Charles A. Allard, chairman of the board of North West Trust Co. Ltd., and president of Allarco Developments Ltd., Edmonton; G. E. Atchison, vice chairman of the board, The Investors Group, Winnipeg; Latham C. Burns, president, Burns Bros. and Denton Ltd., and first vice president, Investment Dealers Association of Canada, Toronto; Arthur H. Crockett, deputy chairman of the board, Bank of Nova Scotia, Toronto; Dr. J. J. Deutsch, principal, Queen's University, Kingston; William B. Harris, Jr., president, Harris & Partners Ltd., Toronto; J. P. S. Mackenzie, vice president, Investment Division, Canada Permanent, Toronto; Walter J. McCarthy, senior vice president, finance, Sun Life Assurance of Canada, Montreal; Claude Prieur, general manager, Caisse de Dépôt et Placement du Québec, Montreal; Raymond Primeau, vice president and general manager, Provincial Bank of Canada,

Montreal; J. A. Rhind, president, National Life Assurance Company of Canada, Toronto; and H. Richard Whittall, partner in Richardson Securities of Canada, Vancouver.

Federal government members are: Jack Austin, deputy minister, Energy, Mines and Resources; S. S. Reisman, deputy minister, Finance; and H. B. Robinson, deputy minister, Indian and Northern Affairs.

Mr. Macdonald will chair the committee meetings with the first one to be held this month. Representatives of the Bank of Canada will attend the meetings as observers.

The terms of reference for the committee are:

—the committee will advise the Minister on the establishment of guidelines to northern pipelines financing for the general information of the Canadian public and in accordance with the guidelines' policy of the government declared on August 13, 1970;

—the committee will review financing proposals for northern pipelines and advise the Minister regarding the viability of those financing proposals and their success in achieving government policy objectives that are to obtain a maximum of equity ownership for Canadian investors and the retention of financial control and management in Canada of such northern pipeline projects; and

—the committee will advise the minister on any means by which financial methods may be designed and implemented to enhance the benefit of any northern pipeline project to the Canadian community.

Mr. Macdonald stated that he wanted to make specific note of the problem of "conflict of interest". None of the advisory committee members are in any way now associated with companies or institutions that will be part owners, paid consultants or advisers to any proposed applicant to build a northern pipeline. "However, I do expect and will, indeed, encourage members to use their expertise and knowledge to assist in financing any northern pipeline project that the government may decide to authorize", Mr. Macdonald said. "Of course, if a specific conflict of interest should arise, I would expect a member of the committee to notify me and to offer a resignation if it appears required".

The Minister noted that deputy ministers Jack Austin and H. B. Robinson serve on the board of directors of Panarctic Oils Ltd., representing the federal government interest in that company.

Mr. Macdonald further stated that no honorarium or remuneration will be paid to the members of the committee but that the members will be reimbursed for out-of-pocket expenses when attending meetings.

EXPANDED GUIDELINES FOR NORTHERN PIPELINES

AS TABLED IN THE HOUSE OF COMMONS BY HON. JEAN CHRÉTIEN

June 28, 1972

Foreword

The Government is today making known its current views on expanded guidelines for the construction and operation of oil and gas pipelines in the Yukon Territory and the Northwest Territories. The proposed guidelines deal with the corridor concept, the environment, and social implications, and are a further elaboration of those announced in August 1970 by the Minister of Energy, Mines and Resources and the Minister of Indian Affairs and Northern Development.

The Government's purpose is expressing these latest views is to give further guidance to industries engaged in research and planning in connection with northern pipelines and to afford the opportunity to northern residents, and all others cocerned to make observations on the guidelines proposed.

In particular, the Government is ready to sit down with the representatives of the native peoples involved, invite their views on the guidelines proposed, and reflect these views wherever possible.

It is the Government's intention, after making any such modifications, to bring these expanded guidelines into force on or about December 31, 1972.

Preamble

Initial Canadian government guidelines for construction and operation of northern pipelines, were announced by the Ministers of the Departments of Energy, Mines and Resources and Indian Affairs and Northern Development in August 1970. At that time, it was stated that further guidelines might be issued. As a result of further studies, research and investigations that have been carried out since 1970, it appears timely to issue expanded guidelines as quickly as possible. Proposed new guidelines on the corridor concept, the environment, and social implications (items 2, 6 and 7 of the August 1970 guidelines) are set out hereunder. These guidelines are Government's current views on what should be included in the northern pipeline guidelines. The Government's purpose in expressing these latest views is to give further guidance to those engaged in research and planning in connection with northern pipelines and to afford the opportunity to northern residents and all others directly concerned to make observations on the proposed guidelines. In particular, the Government is ready to sit down with representatives of the native peoples involved, invite their views on the guidelines proposed, and reflect these views wherever possible. It is the Government's intention, after taking into consideration any observations that may be made, to bring these expanded guidelines into force on or about December 31, 1972. It should be emphasized that the guidelines may be further revised after that date should further pertinent and significant information become available.

Items 2, 6 and 7 of the August 1970 guidelines read as follows:

"2. Initially, only one trunk oil pipeline and one trunk gas pipeline will be permitted to be constructed in the North within a "corridor" to be located and reserved following consultation with industry and other interested groups.

"6. The National Energy Board will ensure that any applicant for a Certificate of Public Convenience and Necessity must document the research conducted and submit a comprehensive report assessing the expected effects of the project upon the environment. Any Certificate issued will be strictly conditioned in respect of preservation of the ecology and environment, prevention of pollution, prevention of thermal and other erosion, freedom of navigation, and the protection of the rights of northern residents, according to standards issued by the Governor General in Council on the advice of the Department of Indian Affairs and Northern Development.

"7. Any applicant must undertake to provide specific programs leading to the employment of residents of the North both during the construction phase and for the operation of the pipeline. For this purpose, the pipeline company will provide for the necessary training of local residents in coordination with various government programs, including on-the-job training projects. The provision of adequate housing and counselling services will also be a requirement."

General

Public comments on the guidelines that follow are invited. Specific comments and suggestions are invited from both the general public and industry with respect to the concept and design of a transportation corridor that might include in the long run not only trunk pipelines, but also a highway, a railroad, electric power transmission lines, telecommunication facilities, etc. Comments and suggestions should be addressed to:

Director,
Environmental-Social Program,
Northern Pipelines,
Room 365D,
Centennial Tower,
400 Laurier Avenue West,
Ottawa, Ontario. K1A OH4.

These guidelines refer only to trunk pipeline systems over land and associated bodies of fresh water on the mainland north of 60° and do not apply to pipelines that may be proposed for the Arctic Islands and intervening marine areas. These guidelines apply to all aspects of oil or gas pipeline pre-construction, construction, operation and abandonment, including not only the actual right-of-way, but also all associated and ancillary facilities such as roads, docks and landing areas, storage areas, airstrips, pumping or compressor stations and communication and maintenance structures.

The term "Applicant" refers to the pipeline applicant, its agents, contractors and subcontractors.

The term "Native People" refers to Indian, Eskimo and Métis people in the Yukon Territory and the Northwest Territories.

In order to translate the intent of these guidelines into action, where this is appropriate, the Applicant will be required to enter into agreements containing covenants that detail specific undertakings. Two general undertakings in each agreement or contract will be: that the Applicant shall be required to post a performance bond respecting the execution of the contractual undertakings, and the security deposit for the bond will be in the form of (a) a promissory note guaranteed by a chartered bank, payable to the Receiver General, or (b) a certified cheque drawn on a chartered bank payable to the Receiver General, or (c) bearer bonds issued or guaranteed by the Government of Canada, or (d) a combination of the securities mentioned in (a), (b) and (c); and that the Applicant shall cooperate with the monitoring service set up by the government to ensure contract compliance, and the cost of the monitoring service will be a charge to the operation.

These guidelines are not to be construed as substitutes for the requirements of applicable acts, ordinances or regulations.

PIPELINES "CORRIDOR" GUIDELINES

Introduction

The 1970 Guidelines made provision for the establishment of a "Corridor" to enclose trunk oil and gas pipelines. The following comments and proposals relate to the application and implementation of this corridor concept.

Purpose and Use of "Corridor" Concept

Control of pipeline routes is required to minimize environmental and social disturbance, to ensure maximum benefits to northern residents and communities, and to channel resource development in accordance with governmental priorities. In approaching the concept of a pipeline "corridor", the Government of Canada recognizes the need for flexibility in the choice of pipeline routing in consideration of resource and market locations, economics, engineering and construction requirements, and the severity and sensitivity of Arctic terrain conditions.

The concept of "one trunk oil pipeline and one trunk gas pipeline" within a "corridor" was enunciated with the intention of confining environmental and social disturbance resulting from trunk pipelines to a narrow zone, thus limiting insofar as possible the geographic area involved in these disturbances and leaving as much as possible of our northern lands in an undisturbed state. On the other hand, it is recognized that restriction of both oil and gas pipeline construction activities to a *narrow* "corridor" would lead to increased intensity of land use and the possibility of unacceptable environmental and social disruption. The routing of oil and gas pipelines close to other transportation-communication systems (and the probability of subsequent development of such systems adjacent to pipelines) may add to problems of maintaining the environment. Even minor disturbances arising from adjacent developmental activities may reinforce one another to produce cumulative ecological disruptions. Moreover, local shortages of gravel or other granular materials may result from close spacing of construction projects. In addition, the differing terrain requirements of oil and gas pipelines may prevent adjacent routings under some circumstances. Thus, caution will be required in defining specific routes or "corridor" boundaries.

"Corridor for Trunk Pipelines in Yukon Territory and Mackenzie Valley Region

Information is presented here concerning the general routing of pipeline "corridors" and applications for pipeline permits across the northern portion of the Yukon Territory and through the Mackenzie Valley region of the Northwest Territories, to carry oil and gas to southern markets from sources in this part of Canada and/or from the Alaska north slope. The present comments apply only to trunk pipelines in the area outlined above, and do not apply to pipelines or "corridors" that may be proposed for other parts of the Yukon Territory and the Northwest Territories.

1. The Government of Canada is prepared to receive and review applications* to construct one trunk oil pipeline and/or one trunk gas pipeline within the following broad "corridors":
   i) Along the Mackenzie Valley region (in a broad sense) from the Arctic coast to the provincial boundary;
   ii) Across the northern part of the Yukon Territory either adjacent to the Arctic coast or through the northern interior region from the boundary of Alaska to the general vicinity of Fort MacPherson, and thus to join the Mackenzie "corridor";

2. To confine the environmental (and social) disturbance arising from pipelines and their construction to a limited area, trunk oil and gas pipelines within the corridors outlined in 1. above are to follow routes are as close together as is consistent with the differing engineering constraints and environmental hazards of the two types of pipelines, but not so close together as to bring about undesirable environmental interaction between the two lines. The same principle is also to apply where the trunk pipeline route lies parallel and near to a present or proposed highway or other overland communication system.

3. In view of the influence of the *first* trunk pipeline in shaping the transportation corridor system and in moulding the environmental and social future of the region, any applicant to build a first trunk pipeline within any segment of the corridor system outlined in 1. above must provide with his application:
   i) assessment of the suitability of the applicant's route for nearby routing of the other pipeline, in terms of the environmental-social and terrain-engineering consequences of the other pipeline and the combined effect of the two pipelines; (fully engineered proposals concerning the other pipeline are not necessarily required);
   ii) assessment of the environmental-social impact of both pipelines on nearby settlements or nearby existing or proposed transportation systems; and
   iii) comparison of the applicant's proposed route with alternative pipeline routes, in terms of environmental and social factors as well as technical and cost considerations; (fully engineered proposals concerning alternative routes are not necessarily required).

4. In relation to the pipeline corridors identified in 1. above, the Government will identify geographic areas of specific environmental and social concern or sensitivity, areas in which it will impose specific restrictions concerning route or pipeline activities, and possibly areas excluded from pipeline construction. These concerns and restrictions will pertain to fishing, hunting, and trapping areas, potential recreation areas, ecologically sensitive areas, hazardous terrain conditions, construction material sources, and other similar matters. Statements announcing the above will be released through the office of the Director, Environmental-Social Program, Northern Pipelines.

5. If and when an applicant has received governmental authorizations to construct and operate any trunk pipeline, it is contemplated that Land Mangement Zones under the

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* Applications are to be filed with the National Energy Board for a Certificate of Public Convenience and Necessity, and with the Department of Indian Affairs and Northern Development, under the Territorial Lands Act, for tenure of land comprising the pipeline right-of-way.

Territorial Lands Act and/or Development Areas under the Area Development Ordinances would be established to encompass the pipeline route and the additional lands required for ancillary facilities such as roads, staging areas, gravel and borrow pits, construction camps, etc.

ENVIRONMENTAL GUIDELINES

Introduction

Guideline No. 6 of August 1970 required that any applicant "must document the research conducted and submit a comprehensive report assessing the expected effects of the project upon the environment". The amplification of this guideline presented below registers some current environmental concerns of government and is intended to indicate to potential applicants some of the major topics that should be included in such an environmental assessment. These concerns are registered in general terms but applicants are to respond in some detail in their environmental assessment with specific engineering design data and proposals that take into consideration the conditions encountered along their particular route. In responding to these concerns, applicants also are to provide documented evidence that they possess not only the necessary knowledge, but also the capability to carry out the specific proposals. As indicated in the 1970 guidelines, applicants will have available, and may be required to submit, all background data upon which the environmental assessment is based. However, the focus should be on specific responses to the concerns outlined below. In connection with these environmental concerns, government may impose restrictions or exclusions on pipeline activities in specific geographic areas that are environmentally sensitive, as outlined in Section 4 of the Pipeline "Corridor" Guidelines.

Guidelines: Some Current Environmental Concerns of Government

Any applicant for a Certificate of Public Convenience and Necessity and for right-of-way and other related land requirements, must submit a comprehensive assessment, based upon documented research, of the expected effects of the project upon the environment. Any certificate issued will be strictly conditioned with respect to applicable statutes providing for the protection of the environment and the following environmental concerns of government:

1. that a pipeline be constructed*, operated and abandoned in keeping with good engineering practice to ensure its safety and integrity, in the interests of good environmental management and the reduction of environmental damage;

2. that construction, operation and abandonment of a pipeline will be done so as to avoid or minimize adverse effects upon the surrounding terrain, including vegetation, and aesthetic damage to the landscape;

3. that rivers and other waterbodies will be approached and crossed, either overhead or underground, in a way that will minimize environmental disturbance to the waterbody itself, to its bed and banks, and to the adjacent land or vegetation during construction, operation, and abandonment of a pipeline;

4. that a pipeline will be constructed, operated and abandoned with a minimal disruption to river and lake regimes, water quality, and feeding, reproduction and migrating stages of fish and other aquatic organisms;

5. that a pipeline will be constructed, operated and abandoned with minimal interference to the lands and vegetation that serve as feeding, reproduction and migrating areas for mammals and wildfowl, and with maximum protection to rare or endangered species and their habitats;

6. that adequate provision be made for disposal of sewage, garbage and various gaseous, liquid and solid wastes and all toxic materials during construction, operation or abandonment phases of the project.

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* Where the words 'construction' or 'constructed' are used they are meant to include preconstruction activities of a pipeline project.

7. that adequate provision be made for preservation or salvage-excavation of archaeological and historical sites, and that minimal damage to such sites will result from pipeline activities.

8. that effective plans be developed to deal with oil leaks, oil spills, pipeline rupture, fire and other hazards to terrestrial, lake and marine habitats, that such plans be designed to minimize environmental disturbances caused by containment, clean-up or other operations and to bring about adequate restoration of the environment, that they be designed to deal with minor and major incidents, whether they are single-event or occur over a period of time and that they include contingency plans to cope with major hazards or critical situations.

9. that an effective plan be developed for implementation of specific environmental safeguards through an educational program for field personnel prior to and during construction and operation of the pipeline;

10. that an effective pipeline performance monitoring system of inspection and instrumentation be established to ensure operational performance in keeping with the above-stated environmental concerns.

Suggested Topics for Response to Environmental Concerns

Examples of the kinds of topics that could be included in an applicant's environmental assessment in response to these environmental concerns of government are presented below. The items are numbered to coincide with the arrangement of the ten environmental concerns in the foregoing section. The listing of topics is not complete and the material is not intended for use as a formal checklist.

It is suggested that *specific proposals* or *information* be presented regarding the following:

1. Safety and integrity of the pipeline (items applicable to this concern are incorporated in concerns 2-10 immediately below).

2. Terrain and vegetation
   a) methods of handling potential problems in relation to earthquakes, landslides, avalanches, or terrain changes resulting from thawing of frozen ground;
   b) methods of minimizing removal of vegetation and the organic mat in permafrost areas with high ice content;
   c) methods of minimizing interference with the movement or quality of water on and in the ground with particular attention given to the expected boundary or limit of influence: where drainage disruptions are expected, the boundary of influence may be well beyond the actual area of construction;
   d) methods of minimizing the loss of strength and volume of soil as a result of melting of ground ice, particularly if the ice occurs in segregated masses; if such melting cannot be entirely prevented then there should be indications of how consequent instability and differential thaw-settlement is to be minimized;
   e) safeguards to be taken against potential dangers to a pipeline from differential vertical movement caused by uneven settlement from thawing of permafrost materials or from "growth" of permafrost; where soil collapse over ice masses and differential flotation and sinking over liquified soil could deform or rupture pipe, proposed safeguards should be identified;
   f) methods of maintaining slope stability in general;
   g) methods of construction and location of permanent facilities in a way that will harmonize with their natural setting;
   h) removal and/or appropriate disposal, of debris created by construction activities and plans for buffer strips of natural vegetation between public roads and pipeline facilities;

i) quantity and quality of aggregate or borrow materials required, details of the geographical distribution of the requirements and proposals as to sources of the required material, including proposed access routes from pit or quarry to point of use, and restoration of pits and quarries;

j) plans to carry out assisted revegetation or alternative methods of providing and insulating cover on which natural revegetation can occur;

3. River and lake crossings

a) for river or stream crossings to be installed beneath the watercourse, depth of maximum anticipated scour and depth of proposed placement of pipe, supported by bore-hole logs and other data indicating the scour depth;

b) design of approaches to river crossings so as to maintain stability of valley walls and river banks and to minimize changes that could lead to slope failures; gullying and related disturbances;

c) design of underground crossings of rivers and streams that could withstand the effects of runoff, bank erosion, meander cutoffs, lateral migration of stream channels, ice jams, and icings, the magnitudes of which should be calculated according to reasonably expected extremes for a particular stream crossing area;

d) design of approaches to and crossings of ponds or lakes, with particular reference to degradation or growth of ground ice, and shore or bank regression or collapse through thermokarst or other processes;

4. River and lake regimes

a) methods for construction of stream and river crossings in a way that will minimize interference with fish passage or degradation of aquatic habitats through erosion and sedimentation;

b) alternative fish passage structures in cases where the proposed project requires stream channel modification that would obstruct migrating fish;

c) schedules of construction activities and evidence that the project contains the flexibility to allow pipeline, road or other construction to cease for periods of time when important areas critical to fish, wildlife, or waterfowl are temporarily threatened;

d) methods of minimizing the addition of sediment and introduction of oils and greases into water bodies as a result of preconstruction or construction activities, particularly in respect to access roads and ice-bridges;

e) proposed location, volume, composition and disposal of pipeline test fluids;

f) plans to restore fish and wildlife habitats that are damaged by pipeline activities;

g) dates and proposed methods of construction within 300 feet of any water body frequented by fish;

5. Wildlife

a) methods of minimizing the restriction of movement of wild animals such as caribou;

b) methods of protection of wetland areas used as feeding, breeding, or staging areas by migratory waterfowl or as habitat for fur-bearers;

c) methods of minimizing harassment and other impact upon wildlife populations from greatly increased human intrusions and the operation of boats, ground vehicles, aircraft, and compressor or pumping stations;

d) safeguards proposed and alternatives that were considered for the habitats of rare or endangered species;

e) control of possession of firearms in construction camps and on construction operations;

6. Waste and toxic material

 a) methods of waste disposal to avoid health hazard to humans and animals as well as aesthetic pollution; information should be provided on use of water from streams, springs or lakes for domestic, camp or construction purposes and on location of camps and sewage disposal systems relative to local drainage patterns;

 b) how ice fog accumulation and air pollution will be minimized;

 c) the nature, transportation and use of any pesticides, herbicides, pipe coating materials, anti-corrosion materials, flushing agents, or other toxic substances, proposed for the project, and information on their expected persistence and mobility in surrounding ecological systems;

7. Archæological sites

 a) archæological surveys to identify prehistoric sites prior to and during construction phases of a pipeline project;

 b) procedures to promote recognition, reporting, and assessment of archæological materials encountered in pipeline activities, including orientation of construction personnel;

 c) arrangements for preservation or salvage-excavation of sites judged to be of archæological significance;

8. Contingency plans

 a) how the possible loss of oil or gas through pipeline leaks would be routinely detected and stopped quickly (the maximum potential undetected loss *from the pipeline* should be specified and evidence provided. This value is to be as low as is technologically feasible);

 b) how oil which has escaped into the terrestrial, lake or marine environment would be detected, how it would be disposed of and how the elements of the environment affected by the oil would be rehabilitated;

 c) methods to prevent burning of vegetation and proposals for a general contingency plan for fire prevention and suppression on the right-of-way, on the immediately surrounding land, and on lands involved in ancillary activities during preconstruction, construction, operation, and abandonment phases of the project;

9. Environmental briefings

 how the applicant intends to carry out environmental briefings to ensure that personnel are fully aware of all environmental restrictions for each construction section and each construction and operational phase of the project, and the reasons for such restrictions;

10. Monitoring

 a) continuous surveillance and maintenance programs along the pipeline right-of-way;

 b) plans to monitor the environmental side effects during and after construction, including downstream sampling of sediment and potentially toxic materials.

SOCIAL GUIDELINES

Introduction

Guideline No. 6 of August 1970 reads in part as follows: "Any certificate issued will be strictly conditioned in respect of . . . the protection of the rights of northern residents . . . ." Government recognizes the concerns of the Indian people of the Territories with regard to the construction and operation of northern pipelines. Government is prepared to discuss with the Indian people their land claims and Treaty rights whenever they express their willingness to meet on the matter, and any decisions made concerning northern pipelines will be with-

out prejudice to Indian land claims and Treaty rights. Guideline No. 7 of August 1970 requires the applicant to undertake specific training programs, to employ residents of the North during the construction and operational phases of the pipeline, and to provide adequate housing and counselling service. The following social guidelines are an elaboration of those issued in 1970. They are consistent with Canada's policy on northern development. They give priority to a higher standard of living and equality of opportunity for northerners by means compatible with their own preferences and aspirations. In addition, they seek to minimize the adverse social and economic consequences associated with rapid large-scale development, where these adverse effects can be predicted with some degree of certainty.

Guidelines

1. The Applicant must undertake specific programs leading to the employment, at all occupational levels, of residents of the territories—and in particular native people, during the construction and operation of the pipeline. Such programs or projects shall include but not be limited to: advance information on all jobs in a manner that ensures that the information reaches potential workers; skills required for various occupations and anticipated duration of employment; upgrading and skill training; other forms of integrated training that include on-the-job work experience; and counselling for those unfamiliar with industrial jobs or wage style living. All training, orientation and counselling courses will be planned and carried out in co-operation with the various agencies of government responsible for these matters. The pipeline companies shall have particular responsibility for on-the-job work experience.

2. Priority placement in jobs shall be accorded native people of the territories in keeping with the tenor of Article 5 of the International Labour Organization Convention 111, 1958, ratified by Canada, and the government's intent to increase employment opportunities for members of disadvantaged minority groups. During the consultation between government, unions and employers as outlined in the Convention, ways and means will be found to ensure access for these employees into the appropriate union locals and hiring halls where there is a requirement. In addition, in accordance with the principle of employment of local workers which is accepted by organized labour, the Applicant will employ labour from the locality where work is being executed to the extent it is available. The Applicant shall comply with the above Convention and employment principles, and cooperate with government's effort to operate an effective recruitment, placement and counselling service.

3. The collective agreements signed by the Applicant and organized labour shall not distinguish between residents of the territories and others respecting special benefits and allowances, including housing for operational staff, and the nature of these benefits shall be in no way inferior for employees from the territories. In addition, in situations where special measures are required to ensure the employment of native people as outlined in the International Labour Convention 111, the Applicant shall negotiate special agreements related to the employment of native people, in consultation with the native people and government.

   Related to the above matters but not restricted thereto is the requirement for the Applicant to set up special orientation and consultation machinery to familiarize its staff and employes with the culture and aspirations of native people and of territorial residents generally. Conversely, this orientation and consultation will acquaint employees from the territories with the pipeline industry and the work habits and life style of non-territorial employees. The orientation and consultation activity shall be planned and operated with the participation of native people, other northern residents, organized labour, the Applicant and the appropriate governmental agency that will coordinate and monitor the various functions performed.

4. Contracts and sub-contracts shall be so designed and publicized as to invite and encourage bids from native organizations, settlement councils and local contractors. In addition,

the businesses and commercial organizations of the territories shall be invited and encouraged to supply goods and services required for the pipeline development and operation.

5. A substantial number of native people depend on trapping and hunting as a principal means of livelihood, and many derive a real satisfaction from being on the land and being master of a familiar environment. Therefore, the pipeline will be constructed, operated and abandoned with minimal interference to traditional trapping, hunting and fishing areas. In addition, where the pipeline construction is planned to be located in proximity to a settlement—particularly a native settlement or localized area subject to intensive use, then the location of construction camps, associated activities and the detailed siting of the pipeline will be decided by government after consultation with the Applicant, and the settlement council, or local government body, or the native organization.

6. Where the construction, operation or abandonment of a pipeline results in loss or damage to the undertakings or property of territorial residents—and native people in particular—then the Applicant shall deal promptly and equitably with all reasonable claims.

7. In order to ensure that the social and economic benefits outweigh the costs, the Applicant shall make a conscious effort to contribute to the social and economic development of the territories. This objective shall have particular relevance regarding; locating permanent infrastructure and maintenance facilities so that their presence will be to the benefit of communities; preserving scarce resources such as aggregate and forest products required by communities—both present and future demands; assuring residents reasonable access to transportation and communication facilities associated with the pipeline system; making gas energy available to selected territorial communities at places and costs to be negotiated between the Applicant and the appropriate governmental agency; and the Applicant shall give prior consideration to the territorial governments—concerning the disposal of all surplus facilities, equipment, or infrastructure, at a place to be negotiated between the Applicant and the respective government.

8. The pipeline construction activity shall be self-sufficient with respect to certain services such as sewer and water, power, roads, fire prevention, recreation services and emergency health services unless there is a prior agreement to the contrary. With respect to other public services that by their nature must remain under public control such as police protection, base hospitals and like services, there will be early consultation with the appropriate level of government to ensure adequate preparation and continuing liaison during the construction and operation phases to ensure maximum coordination and cooperation.

Appendix I

DEPARTMENT OF ENERGY, MINES AND RESOURCES

DEPARTMENT OF INDIAN AFFAIRS AND NORTHERN DEVELOPMENT

For Immediate Release

OTTAWA (August 13, 1970)—Canadian government guidelines for construction and operation of northern oil and gas pipelines were announced jointly today by the Honourable J. J. Greene, Minister of Energy, Mines and Resources, and the Honourable Jean Chrétien, Minister of Indian Affairs and Northern Development.

Knowledge of northern Canada's petroleum potential has been quickly expanding and major companies in the industry have publicly expressed interest in constructing pipelines. Some already have plans and research underway.

It is vital to Canadian economic growth and the protection of our northern environment that the Government of Canada's policies relating to this major economic development be made known now to the public and the industry, the Minister said. Government leadership in policy and direction of this potential major economic contribution will be maintained and, if required, new guidelines will be issued, they added.

The guidelines relate to pipelines tapping oil and gas resources north of the 60th degree of latitude in the Yukon Territory and the Northwest Territories and from Alaska. They establish requirements ranging from environmental protection, pollution control and Canadian ownership and participation to training and employment of residents of the north. Initially, only one trunk line each for oil and gas will be permitted in the north within a "corridor" to be established at a future date.

Mr. Greene and Mr. Chrétien met in Ottawa today with the National Advisory Committee on Petroleum to discuss these requirements with its members and bring the guidelines to the attention of the oil and gas industry as a whole.

The new guidelines for northern pipelines are as follows:

1. The Ministers of Energy, Mines and Resources, and Indian Affairs and Northern Development will function as a point of contact between Government and industry, acting as a Steering Committee from which industry and prospective applicants will receive guidance and direction to those federal departments and agencies concerned with the particular aspects of northern pipelines.

2. Initially, only one trunk oil pipeline and one trunk gas pipeline will be permitted to be constructed in the north within a "corridor" to be located and reserved following consultation with industry and other interested groups.

3. Each of these lines will provide either "common" carrier service at published tariffs or a "contract" carrier service at a negotiated price for all oil and gas which may be tendered thereto.

4. Pipelines in the north, like pipelines elsewhere which are within the jurisdiction of the Parliament of Canada, will be regulated in accordance with the National Energy Board Act, amended as may be appropriate.

5. Means by which Canadians will have a substantial opportunity for participating in the financing, engineering, construction, ownership and management of northern pipelines will form an important element in Canadian goverment consideration of proposals for such pipelines.

6. The National Energy Board will ensure that any applicant for a Certificate of Public Convenience and Necessity must document the research conducted and submit a comprehensive report assessing the expected affects of the project upon the environment. Any certificate issued will be strictly conditioned in respect of preservation of the ecology and environment, prevention of pollution, prevention of thermal and other erosion, freedom of navigation, and the protection of the rights of northern residents, according to standards issued by the Governor General in Council on the advice of the Department of Indian Affairs and Northern Development.

7. Any applicant must undertake to provide specific programs leading to employment of residents of the north both during the construction phase and for the operation of the pipeline. For this purpose, the pipeline company will provide for the necessary training of local residents in coordination with various government programs, including on-the-job training projects. The provision of adequate housing and counselling services will also be a requirement.

The Federal Government will maintain a continuing review of proposals for the construction of northern pipelines and has underway a general review of foreign ownership and control. Further guidelines may be issued as a result of such reviews and would apply to all applications for such pipelines.